Agriculture Business Notes

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Agribusiness

Agribusiness is the business of agricultural production. The term was coined in 1957 by Goldberg and Davis. It includes agrichemicals, breeding, crop production (farming and contract farming), distribution, farm machinery, processing, and seed supply, as well as marketing and retail sales. All agents of the food and fiber value chain and those institutions that influence it are part of the agribusiness system.

Within the agriculture industry, "agribusiness" is used simply as a portmanteau of agriculture and business, referring to the range of activities and disciplines encompassed by modern food production. There are academic degrees in and departments of agribusiness, agribusiness trade associations, agribusiness publications, and so forth, worldwide.

In the context of agribusiness management in academia, each individual element of agriculture production and distribution may be described as agribusinesses. However, the term "agribusiness" most often emphasizes the "interdependence" of these various sectors within the production chain.

Among critics of large-scale, industrialized, vertically integrated food production, the term *agribusiness* is used negatively, synonymous with *corporate farming*. As such, it is often contrasted with smaller family-owned farms.

Examples of agribusinesses include seed and agrichemical producers like Dow AgroSciences, DuPont, Monsanto, and Syngenta; AB Agri (part of Associated British Foods) animal feeds, biofuels, and micro-ingredients, ADM, grain transport and processing; John Deere, farm machinery producer; Ocean Spray, farmer's cooperative; and Purina Farms, agritourism farm.

As concern over global warming intensifies, biofuels derived from crops are gaining increased public and scientific attention. This is driven by factors such as oil price spikes, the need for increased energy security, concern over greenhouse gas emissions from fossil fuels, and support from government subsidies. In Europe and in the US, increased research and production of biofuels has been mandated by law.

Studies of agribusiness often come from the academic fields of agricultural economics and management studies, sometimes called agribusiness management. To promote more development of food economies, many government agencies support the research and publication of economic studies and reports exploring agribusiness and agribusiness practices. Some of these studies are on foods produced for export and are derived from agencies focused on food exports. These agencies include the Foreign Agricultural Service (FAS) of the U.S. Department of Agriculture, Agriculture and Agri-Food Canada(AAFC), Austrade, and New Zealand Trade and Enterprise (NZTE).

The Federation of International Trade Associations publishes studies and reports by FAS and AAFC, as well as other non-governmental organizations on its website.

Ray A. Goldberg coined the term agribusiness together with coauthor John H. Davis. They provided a rigorous economic framework for the field in their book A Concept of Agribusiness (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1957). That seminal work traces a complex value-added chain that begins with the farmer's purchase of seed and livestock and ends with a product fit for the consumer's table. Agribusiness boundary expansion is driven by a variety of transaction costs.

Manuel Alvarado Ledesma (CEMA University, Argentina) and Peter D. Goldsmith (University of Illinois) explain the implications of weak institutions on agribusiness investment. According to them weak institutions lead to policy development and enforcement grounded in the moment, rather than based on precedent and deliberative processes over time.

Agricultural marketing

Agricultural marketing is inferred to cover the services involved in moving an agricultural product from the farm to the consumer. It is also the planning, organizing, directing and handling of agricultural produce in such a way as to satisfy the farmer, producer and the consumer. Numerous interconnected activities are involved in doing this, such as planning production, growing and harvesting, grading, packing and packaging, transport, storage, agro- and food processing, distribution, advertising and sale. Effectively, the term encompasses the entire range of supply chain operations. However, it's key function is to help direct these services, by providing competent and able market information, thereby linking the other operations into an integrated service with targeted outcomes.

Efforts to develop agricultural marketing have, particularly in developing countries, tended to concentrate on a number of areas, specifically infrastructure development; information provision; training of farmers and traders in marketing and post-harvest issues; and support to the development of an appropriate policy environment. In the past, efforts were made to develop government-run marketing bodies but these have tended to become less prominent over the years.

Efficient marketing infrastructure such as wholesale, retail and assembly markets and storage facilities is essential for cost-effective marketing, to minimize post-harvest losses and to reduce health risks. Markets play an important role in rural development, income generation, food security, and developing rural-market linkages. Experience shows that planners need to be aware of how to design markets that meet a community's social and economic needs and how to choose a suitable site for a new market. In many cases sites are chosen that are inappropriate and result in under-use or even no use of the infrastructure constructed. It is also not sufficient just to build a market: attention needs to be paid to how that market will be managed, operated and maintained. Most market improvements that have been only aimed at infrastructure upgrading and have not guaranteed maintenance and management have failed within a few years.

Rural assembly markets are located in production areas and primarily serve as places where farmers can meet with traders to sell their products. These may be occasional (perhaps weekly) markets, such as haat bazaars in India and Nepal, or permanent. Terminal wholesale markets are located in major metropolitan areas, where produce is finally channelled to consumers through trade between wholesalers and retailers, caterers, etc. The characteristics of wholesale markets have changed considerably as retailing changes in response to urban growth, the increasing role of supermarkets and increased consumer spending capacity. These changes may require responses in the way in which traditional wholesale markets are organized and managed.

Retail marketing systems in western countries have broadly evolved from traditional street markets through to the modern hypermarket or out-of-town shopping center. In developing countries, there remains scope to improve agricultural marketing by constructing new retail markets, despite the growth of supermarkets, although municipalities often view markets primarily as sources of revenue rather than infrastructure requiring development. Effective regulation of markets is essential. Inside a market, both hygiene rules and revenue collection activities have to be enforced. Of equal importance, however, is the maintenance of order outside the market. Licensed traders in a market will not be willing to cooperate in raising standards if they face competition from unlicensed operators outside who do not pay any of the costs involved in providing a proper service.

Efficient market information can be shown to have positive benefits for farmers and traders. Up-to-date information on prices and other market factors enables farmers to negotiate with traders and also facilitates spatial distribution of products from rural areas to towns and between markets. Most governments in developing countries have tried to provide market information services to farmers, but these have tended to experience problems of sustainability. Moreover, even when they function, the service provided is often insufficient to allow commercial decisions to be made because of time lags between data collection and dissemination. Modern communications technologies open up the possibility for market information services to improve information delivery through SMS on cell phones and the rapid growth of FM radio stations in many developing countries offers the possibility of more localised information services. In the longer run, the internet may become an effective way of delivering information to farmers. However, problems associated with the cost and accuracy of data collection still remain to be addressed. Even when they have access to market information, farmers often require assistance in interpreting that information. For example, the market price quoted on the radio may refer to a wholesale selling price and farmers may have difficulty in translating this into a realistic price at their local assembly market. Various attempts have been made in developing countries to introduce commercial market information services but these have largely been targeted at traders, commercial farmers or exporters. It is not easy to see how small, poor farmers can generate sufficient income for a commercial service to be profitable although in India a new service introduced by Thomson Reuters was reportedly used by over 100,000 farmers in its first year of operation. Esoko in West Africa attempts to subsidize the cost of such services to farmers by charging access to a more advanced feature set of mobile-based tools to businesses.

Farmers frequently consider marketing as being their major problem. However, while they are able to identify such problems as poor prices, lack of transport and high post-harvest losses, they are often poorly equipped to identify potential solutions. Successful marketing requires learning new skills, new techniques and new ways of obtaining information. Extension officers working with ministries of agriculture or NGOs are often well-trained in horticultural production techniques but usually lack knowledge of marketing or post-harvest handling.

Agricultural marketing needs to be conducted within a supportive policy, legal, institutional, macro-economic, infrastructural and bureaucratic environment. Traders and others are generally reluctant to make investments in an uncertain policy climate, such as those that restrict imports and exports or internal produce movement. Businesses have difficulty functioning when their trading activities are hampered by excessive bureaucracy. Inappropriate law can distort and reduce the efficiency of the market, increase the costs of doing business and retard the development of a competitive private sector. Poor support institutions, such as agricultural extension services, municipalities that operate markets inefficiently and inadequate export promotion bodies, can be particularly damaging. Poor roads increase the cost of doing business, reduce payments to farmers and increase prices to consumers. Finally, corruption can increase the transaction costs faced by those in the marketing chain.

Most governments have at some stage made efforts to promote agricultural marketing improvements. In the United States the Agricultural Marketing Service (AMS) is a division of USDA and has programs that provide testing, support standardization and grading and offer market news services. AMS oversees marketing agreements and orders research and promotion programs. It also purchases commodities for federal food programs. USDA also provides support to agricultural marketing work at various universities. In the United Kingdom, support for marketing of some commodities was provided before and after the Second World War by boards such as the Milk Marketing Board and the Egg Marketing Board. These boards were closed down in the 1970s. As a colonial power, Britain established marketing boards in many countries, particularly in Africa. Some continue to exist although many were closed at the time of the introduction of structural adjustment measures in the 1990s.

Several developing countries have established government-sponsored marketing or agribusiness units. South Africa, for example, started the National Agricultural Marketing Council (NAMC) as a response to the deregulation of the agriculture industry and closure of marketing boards in the country. India has the long-established National Institute of Agricultural Marketing. These are primarily research and policy organizations, but other agencies provide facilitating services for marketing channels, such as the provision of infrastructure, market information and documentation support. Examples from the Caribbean include the National Agricultural Marketing Development Corporation (NAMDEVCO) in Trinidad and Tobago and the New Guyana Marketing Corporation in Guyana.

New marketing linkages between agribusiness, large retailers and farmers are gradually being developed, e.g. through contract farming, group marketing and other forms of collective action. Donors and NGOs are paying increasing attention to ways of promoting direct linkages between farmers and buyers within a value chain context. More attention is now being paid to the development of regional markets (e.g. East Africa) and to structured trading systems that should facilitate such developments. The growth of supermarkets, particularly in Latin America and East and South East Asia, is having a significant impact on marketing channels for horticultural, dairy and livestock products. Nevertheless, “spot” markets will continue to be important for many years, necessitating attention to infrastructure improvement such as for retail and wholesale markets.

Contract farming

Contract farming involves agricultural production being carried out on the basis of an agreement between the buyer and farm producers. Sometimes it involves the buyer specifying the quality required and the price, with the farmer agreeing to deliver at a future date. More commonly, however, contracts outline conditions for the production of farm products and for their delivery to the buyer’s premises. The farmer undertakes to supply agreed quantities of a crop or livestock product, based on the quality standards and delivery requirements of the purchaser. In return, the buyer, usually a company, agrees to buy the product, often at a price that is established in advance. The company often also agrees to support the farmer through, e.g., supplying inputs, assisting with land preparation, providing production advice and transporting produce to its premises. The term "outgrower scheme" is sometimes used synonymously with contract farming, most commonly in Eastern and Southern Africa. Contract farming can be used for many agricultural products, although in developing countries it is less common for staple crops such as rice and maize.

Contract farming has been used for agricultural production for decades but its popularity appears to have been increasing in recent years. The use of contracts has become attractive to many farmers because the arrangement can offer both an assured market and access to production support. Contract farming is also of interest to buyers, who seek supplies of products for sale further along the value chain or for processing. Processors constitute the main users of contracts, as the guaranteed supply enables them to maximise utilization of their processing capacity. Contracts with farmers can also reduce risk from disease or weather and facilitate certification, which is being increasingly demanded by advanced markets. There are also potential benefits for national economies as contract farming leads to economies of scale, which, as Collier and Dercon argue, are "bound to provide for a more dynamic agricultural sector.

Although contract farming must first and foremost be considered as a commercial proposition, it has also come to be viewed as an effective approach to help solve many of the market access and input supply problems faced by small farmers. A guide published by GIZ in 2013 seeks to advise on ways in which contract farming can be developed to maximise such benefits for smallholders in developing countries. Effective linkages between companies and thousands of farmers often require the involvement of formal farmer associations or cooperatives or, at least, informal farmer groups. However, empirical evidence of the best way of achieving this is not yet available.

Eaton and Shepherd identify five different contract farming models. Under the centralized model a company provides support to smallholder production, purchases the crop, and then processes it, closely controlling its quality. This model is used for crops such as tobacco, cotton, sugar cane, banana, tea, and rubber. Under the Nucleus Estate model, the company also manages a plantation in order to supplement smallholder production and provide minimum throughput for the processing plant. This approach is mainly used for tree crops such as oil palm and rubber. The Multipartite model usually involves a partnership between government bodies, private companies and farmers. At a lower level of sophistication, the Intermediary model can involve subcontracting by companies to intermediaries who have their own (informal) arrangements with farmers. Finally, the Informal model involves small and medium enterprises who make simple contracts with farmers on a seasonal basis. Although these are usually just seasonal arrangements they are often repeated annually and usually rely for their success on the proximity of the buyer to the seller.

As with any contract, there are a number of risks associated with contract farming. Common problems include farmers selling to a buyer other than the one with whom they hold a contract (known as side selling, extra-contractual marketing or, in the Philippines, “pole vaulting”), or using inputs supplied by the company for purposes other than intended. From the other side, a company sometimes fails to buy products at the agreed prices or in the agreed quantities, or arbitrarily downgrades produce quality.

The existence of an adequate legal framework is thus crucial for the successful implementation and long-term sustainability of contract farming operations. A system of law is essential to assist farmers and their buyers in the negotiation and drafting of contracts. It is also important to protect them from risks that may occur during contractual execution, such as abuse of power by the stronger bargaining party or breach of contract. Strengthening farmer organisations to improve their contract negotiating skills can redress the potential for subsequent misunderstandings. Different countries have enacted policies and legislation to ensure fair contractual practices and offer remedies for dispute resolution. A “Legal Guide on Contract Farming” was developed in 2013–15 by the International Institute for the Unification of Private Law (UNIDROIT) in partnership with FAO.

Even apparently successful contracts from a legal point of view can face other difficulties. For example, family relationships can be threatened. Work for contracts is often done by women but the contracts are invariably in the name of the man who also receives the payment. Men attend meetings and training courses but women often get no training. Land used by women for food crops or commercial production may be taken over for contract production. This can affect not only food production but also the status of the women. Contracts can break down because of poor management by the company or as a result of unrealistic expectations about the capacity of farmers or about the yields that can be achieved. This has been a particular problem with attempts to promote contract farming for biofuel crops.

Contract farming has to be commercially viable. To maximise profitability companies need to choose the best available farmers. Once suitable farmers have been identified it is then necessary to develop trust, as contracts will only work when both parties believe they are better off by engaging in them. To achieve this requires a willingness to collaborate and share information. Disagreements over product grading, for example, can be avoided by providing clear, simple specifications in a contract and by ensuring that farmers or their representatives are present when the produce is graded. Late payment can immediately cause a breakdown of trust and must be avoided. Contracts should be flexible to take into account the possibility of extreme events such as high open market prices or bad weather. Finally, however hard the parties try, disagreements are inevitable. Contracts should ideally make provision for arbitration by someone acceptable to both the company and the farmers. FAO's *Guiding Principle for Responsible Contract Farming Operations* provides concise advice on how to maximise the chances of success for both companies and farmers. Of particular importance here is the role of producer organisations in bargaining for smallholders' interests.

Numerous studies have been conducted on contract farming ventures and many are listed in the Food and Agriculture Organization's (FAO) Contract Farming Resource Centre,. The Asian Development Bank Institute (ADBI) in Tokyo has conducted a series of case studies in selected Asian countries to assess the conditions for benefits to be achieved by marginal rice farmers. In Lao PDR, the research suggested that contracted farmers earned significantly higher profits than non-contracted farmers. This facilitated the transition of subsistence farmers to commercial agriculture, offering potential to reduce rural poverty. A study in Cambodia on organic rice for export assessed the effect of contract farming on farmers’ performance. This suggested that younger and more educated farmers with larger families and fewer assets were more likely to join the contract. However, farmers with access to good road communications often left the contract, indicating that contract farming had helped them to develop into independent farmers.

A set of papers on the role of contract farming in promoting inclusive market access, published by FAO in 2013, covers contractual arrangements in Argentina, Bangladesh, Brazil, China, Honduras, South Africa, Tanzania and Thailand. The editors conclude that despite a preference for procurement from large farmers, factors other than farm size contribute to a company’s decision and that contract farming will not, therefore, necessarily lead to the exclusion of small farmers from supply chains. Geographical factors are important, both in terms of how they impact on production and in terms of factors such as land rights, gender and ethnic relationships. The editors identify a gradual convergence in clauses and conditions used in contracts and note that the two most common contract provisions, those involving technical assistance and pre-financing of inputs, may be essential for small farmer inclusion. The publication considers the role of third parties, such as NGOs, in coordinating farmers. The editors also identify potential roles for third parties in providing independent quality certification and in certifying contracting companies in order to reduce the risk for farmers.

In considering the subject of “side selling” the FAO publication advocates a combination of favourable incentives and explicit penalties for farmers. It also notes that in some circumstances the costs of full avoidance of contractual breaches can be much greater than losses from side-selling, and that companies may therefore learn to live with side-selling. This will depend on the size of the firm and the amount invested in farmers. Drawing in detail from the case studies, the publication reiterates the importance of a suitable enabling environment. However, it also concludes that in certain cases the lack of such an environment is not necessarily a binding constraint to contract farming, particularly where flexibility and non-conventional contractual clauses can be used. Although an enabling environment is important, the editors caution against government incentives and subsidies to promote inclusion as these may give a misleading impression of profitability and jeopardize sustainability. They also note that the costs to the firm of pursuing an inclusive strategy are rarely considered by proponents of the concept.

Prowse (2012) offers an accessible and comprehensive review of current issues in contract farming in developing countries.

In a study published in 2014, Wang, Wang and Delgado review a large number of empirical studies of contract farming. They conclude that contract farming has had a significant impact on improving farm efficiency and productivity, and farmer incomes.

Several studies offer a positive message on the inclusion of smallholders and the benefits they accrue from participation. For example, in a synthetic review of econometric studies, Minot and Ronchi (2015) suggest that participants' incomes increase by 25-75%. A more measured approach is taken in Ton et al's (2017) systematic review of contract farming, which argues that such figures need to take publication and survivor bias into account. In other words, such estimates need to be revised downwards to accept that studies that show negative or no 'impact' are less likely to be published, and that the calculation of the impact of contract farming may neglect schemes that do not improve incomes for smallholders and collapse and thus are not available for evaluation.

Agrarian reform

Agrarian reform can refer either, narrowly, to government-initiated or government-backed redistribution of agricultural land or, broadly, to an overall redirection of the agrarian system of the country, which often includes land reform measures. Agrarian reform can include credit measures, training, extension, land consolidations, etc. The World Bank evaluates agrarian reform using five dimensions: (1) stocks and market liberalization, (2) land reform (including the development of land markets), (3) agro-processing and input supply channels, (4) urban finance, (5) market institutions.

Ben Cousins defines the difference between agrarian reform and land reform as follows:

Land reform… is concerned with rights in land, and their character, strength and distribution, while… [agrarian reform] focuses not only on these but also a broader set of issues: the class character of the relations of production and distribution in farming and related enterprises, and how these connect to the wider class structure. It is thus concerned economic and political power and the relations between them…

Along similar lines, a 2003 World Bank report states,

…A key precondition for land reform to be feasible and effective in improving beneficiaries' livelihoods is that such programs fit into a broader policy aimed at reducing poverty and establishing a favourable environment for the development of productive smallholder agriculture by beneficiaries.

Examples of other issues include "tenure security" for "farm workers, labour tenants, … farm dwellers… [and] tenant peasants", which makes these workers and tenants better prospects for receiving private-sector loans; "infrastructure and support services"; government support of "forms of rural enterprise" that are "complementary" to agriculture; and increased community participation of government decisions in rural areas.

Agricultural value chain

The agricultural value chain concept has been used since the beginning of the millennium, primarily by those working in agricultural development in developing countries. Although there is no universally accepted definition of the term, it normally refers to the whole range of goods and services necessary for an agricultural product to move from the farm to the final customer or consumer.

The term value chain was first popularized in a book published in 1985 by Michael Porter, who used it to illustrate how companies could achieve what he called “competitive advantage” by adding value within their organization. Subsequently, the term was adopted for agricultural development purposes and has now become very much in vogue among those working in this field, with an increasing number of bilateral and multilateral aid organisations using it to guide their development interventions.

At the heart of the agricultural value chain concept is the idea of actors connected along a chain producing and delivering goods to consumers through a sequence of activities. However, this “vertical” chain cannot function in isolation and an important aspect of the value chain approach is that it also considers “horizontal” impacts on the chain, such as input and finance provision, extension support and the general enabling environment. The approach has been found useful, particularly by donors, in that it has resulted in a consideration of all those factors impacting on the ability of farmers to access markets profitably, leading to a broader range of chain interventions. It is used both for upgrading existing chains and for donors to identify market opportunities for small farmers.

There is no commonly agreed definition of what is actually meant by agricultural value chains. Indeed, some agencies are using the term without having a workable definition or definitions and simply redefined ongoing activities as “value chain” work when the term came into vogue. Published definitions include the World Bank’s “the term ‘’value chain’’ describes the full range of value adding activities required to bring a product or service through the different phases of production, including procurement of raw materials and other inputs”, UNIDO’s “actors connected along a chain producing, transforming and bringing goods and services to end-consumers through a sequenced set of activities and CIAT’s “a strategic network among a number of business organizations”.

Without a universal definition the term “value chain” is now being used to refer to a range of types of chain, including:

- An international, or regional commodity market. Examples could include “the global cotton value chain”, “the southern African maize value chain” or “the Brazilian coffee value chain”;
- A national or local commodity market or marketing system such as “the Ghanaian tomato value chain” or “”the Accra tomato value chain”;
- A supply chain, which can cover both of the above;
- An extended supply chain or marketing channel, which embraces all activities needed to produce the product, including information/extension, planning, input supply and finance. It is probably the most common usage of the value chain term;
- A dedicated chain designed to meet the needs of one or a limited number of buyers. This usage, which is arguably most faithful to Porter’s concept, stresses that a value chain is designed to capture value for all actors by carrying out activities to meet the demand of consumers or of a particular retailer, processor or food service company supplying those consumers. Emphasis is firmly placed on demand as the source of the value.

Donors and others supporting agricultural development, such as GIZ, DFID, ILO, IIED and UNIDO, have produced a range of documents designed to assist their staff and others to evaluate value chains in order to decide on the most appropriate interventions to either update existing chains or promote new ones. However, the application of value chain analysis is being interpreted differently by different organisations, with possible repercussions for their development impact. The proliferation of guides has taken place in an environment where key conceptual and methodological elements of value chain analysis and development are still evolving. Many of these guides include not only detailed procedures that require experts to carry out the analysis but also use detailed quasi-academic methodologies. One such methodology is to compare the same value chain over time (a comparative or panel study) to assess changes in rents, governance, systemic efficiency and the institutional framework.

A major subset of value chain development work is concerned with ways of linking producers to companies, and hence into the value chains. While there are examples of fully integrated value chains that do not involve smallholders (e.g. Unilever operates tea estates and tea processing facilities in Kenya and then blends and packs the tea in Europe before selling it as Lipton, Brooke Bond or PG Tips brands), the great bulk of agricultural value chains involve sales to companies from independent farmers. Such arrangements frequently involve contract farming in which the farmer undertakes to supply agreed quantities of a crop or livestock product, based on the quality standards and delivery requirements of the purchaser, often at a price that is established in advance. Companies often also agree to support the farmer through input supply, land preparation, extension advice and transporting produce to their premises.

Work to promote market linkages in developing countries is often based on the concept of “inclusive value chains”, which usually places emphasis on identifying possible ways in which small-scale farmers can be incorporated into existing or new value chains or can extract greater value from the chain, either by increasing efficiency or by also carrying out activities further along the chain. In the various publications on the topic the definition of “inclusion” is often imprecise as it is often unclear whether the development aim is to include all farmers or only those best able to take advantage of the opportunities.

Agricultural value chain finance is concerned with the flows of funds to and within a value chain to meet the needs of chain actors for finance, to secure sales, to buy inputs or produce, or to improve efficiency. Examining the potential for value chain finance involves a holistic approach to analyze the chain, those working in it, and their inter-linkages. These linkages allow financing to flow through the chain. For example, inputs can be provided to farmers and the cost can be repaid directly when the product is delivered, without need for farmers taking a loan from a bank or similar institution. This is common under contract farming arrangements. Types of value chain finance include product financing through trader and input supplier credit or credit supplied by a marketing company or a lead firm. Other trade finance instruments include receivables financing where the bank advances funds against an assignment of future receivables from the buyer, and factoring in which a business sells its accounts receivable at a discount. Also falling under value chain finance are asset collateralization, such as on the basis of warehouse receipts, and risk mitigation, such as forward contracting, futures and insurance.

Information and Communication Technologies, or ICTs, have become an important tool in promoting agricultural value chain efficiency. There has been a rapid expansion in the use of mobile technologies, in particular. The price of ICT services is falling and the technologies are becoming more affordable to many in developing countries. Applications can support farmers directly through SMS messages. Examples include iCow, developed in Kenya, which provides information on the gestation period, on artificial insemination of the cows, and on how to look after them. Applications such as M-Pesa can support access to mobile payment services for a large percentage of those without banks, thereby facilitating transactions in the value chain. Other applications have been developed to promote provision of crop insurance through input dealers, for example.

ICTs are also being used to strengthen the capacity of extension officers and NGO field staff to reach farmers with timely and accurate information and, at the same time, help capture data from the field. The Grameen Foundation's Community Knowledge Worker (CKW) programme is an example. Farmer representatives are trained to use ICT applications on a smartphone to provide agricultural information and extension support. Most market price information is now delivered to farmers via SMS. Further along the chain, technologies offer considerable possibilities to enhance traceability, which is particularly relevant as certification grows in importance. Where necessary many exporters can now trace consignments back to individual farmers and take necessary measures to address problems. Finally, systems such as FARA's eRails are also supporting agricultural researchers through data collection and analysis and access to up-to-date research publications.

As with all agricultural growth, two things appear essential for successful value chain development: creating the right environment for agriculture and investing in rural public goods. An enabling environment implies peace and public order, macro-economic stability, inflation under control, exchange rates based on market fundamentals rather than government allocation of foreign currency, predictable taxation that is reinvested in public goods and property rights. There is a positive correlation of agricultural growth with investment in irrigation, transport infrastructure and other technologies. Governments have a responsibility to provide essential goods and services, infrastructure, such as rural roads, and agricultural research and extension. Value chain development is often constrained by corruption, both at a high level and at the ubiquitous road blocks found in many countries, particularly in Africa. Many measures to improve value chains require collaboration between a wide range of different ministries, and this can be difficult to achieve.

Agricultural machinery industry

The agricultural machinery industry or agricultural engineering industry is the part of the industry, that produces and maintain tractors, agricultural machinery and agricultural implements. This branch is considered to be part of the machinery industry.

The agricultural machinery industry emerged in Britain and the United States in the 19th century. Until then the common tools of farming were the plough and the sickle. These iron agricultural implements were often made by blacksmiths in the local village, who regularly also acted as farrier. In the first part of the 19th century some of the early agricultural machine manufacturers arose from these blacksmith workshops, such as John Deere who started up with the production of ploughs in series in the 1840s.

Other companies arose from the introduction of horse drawn reaping, which replaced the type of hand reaper in use since biblical times. A company as the McCormick started up with building these kind of harvesting machines around the 1840s. And another origin of agricultural industry was the introduction of combined harvesting, threshing and cleaning in the 1830s. The Case Corporation for example started building those in 1842 as the Racine Threshing Machine Works. Until early 20th century most of those machinery were powered by horses.

Mid 19th century the portable steam-powered plowing engines were introduced. They were used in pairs, placed on either side of a field to haul a plow back and forth between them using a wire cable. These portable engines were also used to power threshing machines, mills and pumps. The portable steam engines were produced by specific agricultural machinery maker, such as Ransomes, Sims & Jefferieswho had started as brass and iron-founder making casting ploughshares late 18th century.

Late 19th century in Britain more companies such as Richard Garrett & Sons and Mann’s Patent Steam Cart and Wagon Company developed steam tractors for direct ploughing, but the heavy, wet soil of England meant that these designs were less economical than a team of horses. In the United States, where soil conditions permitted, steam tractors were used to direct-haul plows. Steam-powered agricultural engines remained in use well into the 20th century until reliable internal combustion engines had been developed.

Collins (1987) recalled that the impact of the agricultural machinery industry in the 19th century was still limited. He stated : "prior the third quarter of the nineteenth century the impact of machinery in agriculture was slight compared with that in manufacturing industry. Some operations such as barn work and hay and corn harvesting had been largely mechanized by 1880 but, up to the Second World War, many were still performed by hand labour and large numbers of workers were still required for seasonal tasks such as hop- and fruit-picking and vegetable cultivations."

In the beginning of the 20th century in the UK the Agricultural machinery industry "although composed of many hundreds of firms, was dominated by a few large ones, chiefly in the eastern counties of England. The total output of the industry was estimated to be worth 6.5 million pounds in 1913, or about 5 percent of the total value of the output of the mechanical engineering industry at the first Census of Production in 1907."

In the first decennia the internal combustion engine; first the petrol engine, and later diesel engines; became the main source of power for the next generation of tractors. Early companies expanded into the tractor business, such as John Deere which bought the Waterloo Gasoline Engine Company in 1918, which manufactured the popular Waterloo Boy tractor. In the 1930s new technologies as rubber ties and hydrologics were introduced in tractors and other farm machinery. The diesel engines also contributed to the development of the self-propelled, combined harvester and thresher, or combine harvester (also shortened to 'combine'). Instead of cutting the grain stalks and transporting them to a stationary threshing machine, these combines cut, threshed, and separated the grain while moving continuously through the field.

In the second part of the 20th century the production of agricultural machinery in development countries rose rapidly. In the 1960s a country as the UK exported more than 60% of its production to Western Europe, Australia, USA, Canada and South Africa, and main manufacturers started production plants abroad. Another trend was the increased concentration among manufacturers. In the 1970s in the UK six companies supplied 75% of the total output.

The further mechanization of agriculture in the 20th century made possible by the agricultural machinery industry had a huge impact of the economic structure of society. In the developed countries the total labour force engaged in agriculture dropped from about 75% in 1800 to less than 5% late 20th century. In developing countries, in late 20th century still 75% of all land "was farmed with only hand-tools and draught-animal technology." In Turkey still 48% and in India 66.5% of the labor were working in agriculture, according to the FAO Production Yearbook 1990.

A 2013 report by the VDMA gave the following preview of the current developments in the agricultural machinery industry:

> "*The general trends in society, agriculture and technology allow conclusions about the future requirements profile for agricultural machinery... The depicted dominating topics for the agricultural sector are*
>
> - *Precision & automation*
> - *Efficiency & user friendliness*
> - *Communication & networking*
>
> *These topics are today already central components of the specifications for new developments...*"

The agricultural machinery industry produces agricultural machinery, machinery used in the operation of agricultural areas and farms. Main types are:

- Tractors and power.
- Machinery for tillage or soil cultivation.
- Machinery for planting, seeding, fertilizing, pest control, irrigation.
- Machinery for harvesting, haymaking, and post-harvest, such as produce sorters, and machinery for loading
- Machinery for milking
- Other agricultural machinery, for example grinder mixers, wool presses and windmills.

In developed countries overall the largest segment of agricultural equipment sales is tractors.

Agricultural machinery manufacturers exist in sizes from small and medium business to multinationals. James & Akrasanee (1988) stipulated that those forms have different production management, and can be classified into three groups:

- *The first group consists of those workshops with limited and simple equipment. Despite their flexibility, the production management system is very rare in this case.*
- *The second group includes those with certain degrees of division of labour within the plant. They do organize some plant layout, but not in a fully systematic manner.*
- *The last group constitutes those with clear production lines and division of labour.*

The two largest agricultural machinery manufacturers worldwide based on revenue (in 2012):

- John Deere : $37.79 billion revenues and employing 67,000 people worldwide in 2013. Its workforce has increased significantly in the past decennia from 43.000 in 2002 to 67.000 in 2013.
- CNH Global : $19.4 billion revenues and employing 33.800 people worldwide in 2013.

In the United States the revenue of tractor & agricultural machinery manufacturing sector increased from about 35 billion U.S. dollars in 2009 to 42 billion U.S. dollars in 2014.

Some of the more important agricultural machinery associations are:

- Agricultural Engineers Association (AEA): British trade association which represents manufacturers and importers of agricultural machinery and outdoor equipment.
- Agrievolution: global network of agricultural machinery associations.
- Association of Equipment Manufacturers (AEM): American association which represents manufacturers of agricultural machinery.
- CEMA: European association representing the agricultural machinery industry in Europe.
- VDMA Agricultural Machinery Association: German manufacturers' association which represents manufacturers of agricultural machinery.
- ANSEMAT Association of agricultural machinery manufacturers in Spain.

According to the CEMA, the European association representing the European agricultural machinery industry, Europe was the largest producer of agricultural machinery globally in 2013:

- Europe produced 31% of the global production
- North America produced 26.5% of the global production,
- China produced 26.5% of the global production, and
- The remaining 16% is produced elsewhere.

In total, the production of agricultural machinery worldwide in 2013 generated about 95 billion euros, based on a report *Agricultural Machinery November 2013 : Market Perspectives 2014* by the VDMA, a German engineering association. Another recent statistic mentioned, that the agricultural machinery industry in 2010 generated worldwide about $56 billion.

Yuan'en (2007) stated, that the "Chinese government has attached great importance to agriculture, rural areas and farmers, made a series of policies that favorite to the farmers, added the financial subsidy to the agriculture, especially constituted the subsidy policies for the farmers on their agricultural machinery purchasing."

A 2013-2014 report acknowledged that "China's agricultural machinery industry has achieved rapid development, the gross output value of agricultural machinery exceeded RMB 300 billion, total power of agricultural machinery surpassed 1 billion kilowatts, and the integrated mechanization level of agricultural crops exceeded 50%, demonstrating that China has entered into a mechanized production-oriented period.... Tractors and harvesting machinery are the most important agricultural machinery products in China, with annual output of 2.25 million units and 1.114 million units in 2012 separately...

Gyanendra (2006) recalled, that "the early agricultural mechanization in India was greatly influenced by the technological development in England. Irrigation pumps, tillage equipment, chaff cutters, tractors and threshers were gradually introduced for farm mechanization. The high yielding varieties with assured irrigation and higher rate of application of fertilizers gave higher returns that enabled farmers to adopt mechanization inputs, especially after Green revolution in 1960s."

The Turkish Ministry of Economy (2011) explained that "Turkey is one of the few countries of the world which is self-sufficient in food. At present Turkey is the largest producer and exporter of agricultural products in the Near East and North

Africa... The agricultural machinery industry is comprised of about 1000 manufacturers countrywide.... Companies manufacturing agricultural machinery and equipment except tractors are mostly small and medium size companies. The sector employs about 15,000 workers... The value of agricultural machinery and spare parts and agricultural tractors and trailers exports was US$ 313 million in 2009."

With a volume of 28 billion euros (2014) agricultural machinery production in the European Union (EU) represented 28 per cent of world total according to VDMA. Out of the EU total, the share of Germany is 27 per cent, followed by Italy (17 per cent) and France (14 per cent). All leading international manufacturers have several production sites on the European continent, and their products from these factories in general are destined for the high end customers who yield for efficiency and accuracy on the fields.

The EU production of tractors was 187,000 units, correspondent to a value of 9.4 billion euros (2014). Outside the EU, a major production site for tractors is the Minsk Tractor Works (Belarus) with a high market share in the neighbouring countries, especially within the Commonwealth of Independent States. The leading countries for tractor production in the EU are Germany and Italy (with John Deere, Case New Holland, AGCO and Same Deutz-Fahr being the major brands). Germany is also the major place for the manufacturing of harvesting, spraying, fertilizing and seeding equipment. Italy and France have a primary position for soil working machines and transportation vehicles. The majority of the agricultural machinery companies are small and medium-sized and family owned.

One third of the EU production is destined to markets outside the union, mainly to the Eastern European markets, but also to North America and, increasingly, to Asia.

After a peak in 2003 and 29 billion euros of turnover, the sector experienced an economic downturn in 2014/2015. The strategy of the European industry is to keep its leading technological position and to diversify its market presence into the high potential regions .

The AEM (2014) stated that "U.S. domestic sales of agricultural machinery and equipment rose from about $20 billion in 1999 to $38 billion in 2012. Since 1998 and through 2012, U.S. exports of agricultural equipment have grown relatively quickly, more than doubling from about $4 billion to $8.7 billion.

Graciela summarized (2008) that "the agricultural machinery industry in Argentina depends for growth on higher exports and further progress towards internationalization, which are strategic goals for the largest firms. Given the dynamism of global demand for this type of machinery, the conclusion is that the sector can increase its sales in export markets, where some of its products are competing well."

Agroecology

Agroecology is the study of ecological processes applied to agricultural production systems. The prefix *agro*- refers to *agriculture*. Bringing ecological principles to bear in agroecosystems can suggest novel management approaches that would not otherwise be considered. The term is often used imprecisely and may refer to "a science, a movement, [or] a practice". Agroecologists study a variety of agroecosystems, and the field of agroecology is not associated with any one particular method of farming, whether it be organic, integrated, or conventional; intensive or extensive, although it has much more in common with some of the before mentioned farming systems.

Agroecologists do not unanimously oppose technology or inputs in agriculture but instead assess how, when, and if technology can be used in conjunction with natural, social and human assets. Agroecology proposes a context- or site-specific manner of studying agroecosystems, and as such, it recognizes that there is no universal formula or recipe for the success and maximum well-being of an agroecosystem. Thus, agroecology is not defined by certain management practices, such as the use of natural enemies in place of insecticides, or polyculture in place of monoculture.

Instead, agroecologists may study questions related to the four system properties of agroecosystems: productivity, stability, sustainability and equitability. As opposed to disciplines that are concerned with only one or some of these properties, agroecologists see all four properties as interconnected and integral to the success of an agroecosystem. Recognizing that these properties are found on varying spatial scales, agroecologists do not limit themselves to the study of agroecosystems at any one scale: gene-organism-population-community-ecosystem-landscape-biome, field-farm-community-region-state-country-continent-global.

Agroecologists study these four properties through an interdisciplinary lens, using natural sciences to understand elements of agroecosystems such as soil properties and plant-insect interactions, as well as using social sciences to understand the effects of farming practices on rural communities, economic constraints to developing new production methods, or cultural factors determining farming practices.

Agroecologists do not always agree about what agroecology is or should be in the long-term. Different definitions of the term agroecology can be distinguished largely by the specificity with which one defines the term "ecology", as well as the term's potential political connotations. Definitions of agroecology, therefore, may be first grouped according to the specific contexts within which they situate agriculture. Agroecology is defined by the OECD as "the study of the relation of agricultural crops and environment." This definition refers to the "-ecology" part of "agroecology" narrowly as the natural environment. Following this definition, an agroecologist would study agriculture's various relationships with soil health, water quality, air quality, meso- and micro-fauna, surrounding flora, environmental toxins, and other environmental contexts.

A more common definition of the word can be taken from Dalgaard et al., who refer to agroecology as the study of the interactions between plants, animals, humans and the environment within agricultural systems. Consequently, agroecology is inherently multidisciplinary, including factors from agronomy, ecology, sociology, economics and related disciplines. In this case, the "-ecology" portion of "agroecology is defined broadly to include social, cultural, and economic contexts as well. Francis et al. also expand the definition in the same way, but put more emphasis on the notion of food systems.

Agroecology is also defined differently according to geographic location. In the global south, the term often carries overtly political connotations. Such political definitions of the term usually ascribe to it the goals of social and economic justice; special attention, in this case, is often paid to the traditional farming knowledge of indigenous populations. North American and European uses of the term sometimes avoid the inclusion of such overtly political goals. In these cases, agroecology is seen more strictly as a scientific discipline with less specific social goals.

This approach is derived from the science of ecology primarily based on population ecology, which over the past three decades has been displacing the ecosystems biology of Odum. Buttel explains the main difference between the two categories, saying that "the application of population ecology to agroecology involves the primacy not only of analyzing agroecosystems from the perspective of the population dynamics of their constituent species, and their relationships to climate and biogeochemistry, but also there is a major emphasis placed on the role of genetics."

This concept was proposed by political ecologist Josep Garí to recognise and uphold the integrated agro-ecological practices of many indigenous peoples, who simultaneously and sustainably safeguard, manage and use ecosystems for agricultural, food, biodiversity and cultural purposes at the same time. Indigenous agroecologies are not systems and practices halted in time, but keep co-evolving with new knowledge and resources, such as that provided by development projects, research initiatives and agro-biodiversity exchanges. In fact, the first agro-ecologists were indigenous peoples that advocated development policies and programmes to support their systems, rather than replacing them.

Rather than viewing agroecology as a subset of agriculture, Wojtkowski takes a more encompassing perspective. In this, natural ecology and agroecology are the major headings under ecology. Natural ecology is the study of organisms as they interact with and within natural environments. Correspondingly, agroecology is the basis for the land-use sciences. Here humans are the primary governing force for organisms within planned and managed, mostly terrestrial, environments.

As key headings, natural ecology and agroecology provide the theoretical base for their respective sciences. These theoretical bases overlap but differ in a major way. Economics has no role in the functioning of natural ecosystems whereas economics sets direction and purpose in agroecology.

Under agroecology are the three land-use sciences, agriculture, forestry, and agroforestry. Although these use their plant components in different ways, they share the same theoretical core.

Beyond this, the land-use sciences further subdivide. The subheadings include agronomy, organic farming, traditional agriculture, permaculture, and silviculture. Within this system of subdivisions, agroecology is philosophically neutral. The importance lies in providing a theoretical base hitherto lacking in the land-use sciences. This allows progress in biocomplex agroecosystems including the multi-species plantations of forestry and agroforestry.

To arrive at a point of view about a particular way of farming, an agroecologist would first seek to understand the contexts in which the farm(s) is(are) involved. Each farm may be inserted in a unique combination of factors or contexts. Each farmer may have their own premises about the meanings of an agricultural endeavor, and these meanings might be different from those of agroecologists.

Generally, farmers seek a configuration that is viable in multiple contexts, such as family, financial, technical, political, logistical, market, environmental, spiritual. Agroecologists want to understand the behavior of those who seek livelihoods from plant and animal increase, acknowledging the organization and planning that is required to run a farm.

Because organic agriculture proclaims to sustain the health of soils, ecosystems, and people, it has much in common with Agroecology; this does not mean that Agroecology is synonymous with organic agriculture, nor that Agroecology views organic farming as the 'right' way of farming. Also, it is important to point out that there are large differences in organic standards among countries and certifying agencies.

Three of the main areas that agroecologists would look at in farms, would be: the environmental impacts, animal welfare issues, and the social aspects.

Environmental impacts caused by organic and non-organic milk production can vary significantly. For both cases, there are positive and negative environmental consequences.

Compared to conventional milk production, organic milk production tends to have lower eutrophication potential per ton of milk or per hectare of farmland, because it potentially reduces leaching of nitrates (NO_3^-) and phosphates (PO_4^-) due to lower fertilizer application rates. Because organic milk production reduces pesticides utilization, it increases land use per ton of milk due to decreased crop yields per hectare. Mainly due to the lower level of concentrates given to cows in organic herds, organic dairy farms generally produce less milk per cow than conventional dairy farms. Because of the increased use of roughage and the, on-average, lower milk production level per cow, some research has connected organic milk production with increases in the emission of methane.

Animal welfare issues vary among dairy farms and are not necessarily related to the way of producing milk (organically or conventionally).

A key component of animal welfare is freedom to perform their innate (natural) behavior, and this is stated in one of the basic principles of organic agriculture. Also, there are other aspects of animal welfare to be considered – such as freedom from hunger, thirst, discomfort, injury, fear, distress, disease and pain. Because organic standards require loose housing systems, adequate bedding, restrictions on the area of slatted floors, a minimum forage proportion in the ruminant diets, and tend to limit stocking densities both on pasture and in housing for dairy cows, they potentially promote good foot and hoof health. Some studies show lower incidence of placenta retention, milk fever, abomasums displacement and other diseases in organic than in conventional dairy herds. However, the level of infections by parasites in organically managed herds is generally higher than in conventional herds.

Social aspects of dairy enterprises include life quality of farmers, of farm labor, of rural and urban communities, and also includes public health.

Both organic and non-organic farms can have good and bad implications for the life quality of all the different people involved in that food chain. Issues like labor conditions, labor hours and labor rights, for instance, do not depend on the organic/non-organic characteristic of the farm; they can be more related to the socio-economical and cultural situations in which the farm is inserted, instead.

As for the public health or food safety concern, organic foods are intended to be healthy, free of contaminations and free from agents that could cause human diseases. Organic milk is meant to have no chemical residues to consumers, and the restrictions on the use of antibiotics and chemicals in organic food production has the purpose to accomplish this goal. Although dairy cows in both organic and conventional farming practices can be exposed to pathogens, it has been shown that, because antibiotics are not permitted as a preventative measure in organic practices, there are far fewer antibiotic resistant pathogens on organic farms. This dramatically increases the efficacy of antibiotics when/if they are necessary.

No-tillage is one of the components of conservation agriculture practices and is considered more environmental friendly than complete tillage. There is a general consensus that no-till can increase soils capacity of acting as a carbon sink, especially when combined with cover crops.

No-till can contribute to higher soil organic matter and organic carbon content in soils, though reports of no-effects of no-tillage in organic matter and organic carbon soil contents also exist, depending on environmental and crop conditions. In addition, no-till can indirectly reduce CO_2 emissions by decreasing the use of fossil fuels.

Most crops can benefit from the practice of no-till, but not all crops are suitable for complete no-till agriculture. Crops that do not perform well when competing with other plants that grow in untilled soil in their early stages can be best grown by using other conservation tillage practices, like a combination of strip-till with no-till areas. Also, crops which harvestable portion grows underground can have better results with strip-tillage, mainly in soils which are hard for plant roots to penetrate into deeper layers to access water and nutrients.

The benefits provided by no-tillage to predators may lead to larger predator populations, which is a good way to control pests (biological control), but also can facilitate predation of the crop itself. In corn crops, for instance, predation by caterpillars can be higher in no-till than in conventional tillage fields.

In places with rigorous winter, untilled soil can take longer to warm and dry in spring, which may delay planting to less ideal dates. Another factor to be considered is that organic residue from the prior year's crops lying on the surface of untilled fields can provide a favorable environment to pathogens, helping to increase the risk of transmitting diseases to the future crop. And because no-till farming provides good environment for pathogens, insects and weeds, it can lead farmers to a more intensive use of chemicals for pest control. Other disadvantages of no-till include underground rot, low soil temperatures and high moisture.

Based on the balance of these factors, and because each farm has different problems, agroecologists will not attest that only no-till or complete tillage is the right way of farming . Yet, these are not the only possible choices regarding soil preparation, since there are intermediate practices such as strip-till, mulch-till and ridge-till, all of them – just as no-till – categorized as conservation tillage. Agroecologists, then, will evaluate the need of different practices for the contexts in which each farm is inserted.

The notions and ideas relating to crop ecology have been around since at least 1911 when F.H. King released *Farmers of Forty Centuries*. King was one of the pioneers as a proponent of more quantitative methods for characterization of water relations and physical properties of soils. In the late 1920s the attempt to merge agronomy and ecology was born with the development of the field of crop ecology. Crop ecology's main concern was where crops would be best grown. Actually, it was only in 1928 that agronomy and ecology were formally linked by Klages.

The first mention of the term agroecology was in 1928, with the publication of the term by Bensin in 1928. The book of Tischler (1965), was probably the first to be actually titled 'agroecology'. He analysed the different components (plants, animals, soils and climate) and their interactions within an agroecosystem as well as the impact of human agricultural management on these components. Other books dealing with agroecology, but without using the term explicitly were published by the German zoologist Friederichs (1930) with his book on agricultural zoology and related ecological/environmental factors for plant protection, and by American crop physiologist Hansen in 1939 when both used the word as a synonym for the application of ecology within agriculture.

Gliessman mentions that post-WWII, groups of scientists with ecologists gave more focus to experiments in the natural environment, while agronomists dedicated their attention to the cultivated systems in agriculture. According to Gliessman, the two groups kept their research and interest apart until books and articles using the concept of agroecosystems and the word agroecology started to appear in 1970. Dalgaard explains the different points of view in ecology schools, and the fundamental differences, which set the basis for the development of agroecology. The early ecology school of Henry Gleason investigated plant populations focusing in the hierarchical levels of the organism under study.

Friederich Clement's ecology school, however included the organism in question as well as the higher hierarchical levels in its investigations, a "landscape perspective". However, the ecological schools where the roots of agroecology lie are even broader in nature. The ecology school of Tansley, whose view included both the biotic organism and their environment, is the one from which the concept of agroecosystems emerged in 1974 with Harper.

In the 1960s and 1970s the increasing awareness of how humans manage the landscape and its consequences set the stage for the necessary cross between agronomy and ecology. Even though, in many ways the environmental movement in the US was a product of the times, the green decade spread an environmental awareness of the unintended consequences of changing ecological processes. Works such as *Silent Spring*, and *The Limits to Growth*, and changes in legislation such as the Clean Air Act, Clean Water Act, and the National Environmental Policy Act caused the public to be aware of societal growth patterns, agricultural production, and the overall capacity of the system.

After the 1970s, when agronomists saw the value of ecology and ecologists began to use the agricultural systems as study plots, studies in agroecology grew more rapidly. Gliessman describes that the innovative work of Prof. Efraim Hernandez X., who developed research based on indigenous systems of knowledge in Mexico, led to education programs in agroecology. In 1977 Prof. Efraim Hernandez X. explained that modern agricultural systems had lost their ecological foundation when socio-economic factors became the only driving force in the food system. The acknowledgement that the socio-economic interactions are indeed one of the fundamental components of any agroecosystems came to light in 1982, with the article Agroecologia del Tropico Americano by Montaldo. The author argues that the socio-economic context cannot be separated from the agricultural systems when designing agricultural practices.

In 1995 Edens et al. in Sustainable Agriculture and Integrated Farming Systems solidified this idea proving his point by devoting special sections to economics of the systems, ecological impacts, and ethics and values in agriculture. Actually, 1985 ended up being a fertile and creative year for the new discipline. For instance in the same year, Miguel Altieri integrated how consolidation of the farms, and cropping systems impact pest populations. In addition, Gliessman highlighted that socio-economic, technological, and ecological components give rise to producer choices of food production systems. These pioneering agroecologists have helped to frame the foundation of what we today consider the interdisciplinary field of agroecology and have led to advances in a number of farming systems. In Asian rice, for example, crop diversification by growing flowering crops in strips beside rice fields has recently been demonstrated to reduce pests so effectively (by the flower nectar attracting and supporting parasitoids and predators) that insecticide spraying is reduced by 70%, yields increase by 5%, together resulting in an economic advantage of 7.5% .

The principles of agroecology are expressed differently depending on local ecological and social contexts.

Latin America's experiences with North American Green Revolution agricultural techniques have opened space for agroecologists. Traditional or indigenous knowledge represents a wealth of possibility for agroecologists, including "exchange of wisdoms". See Miguel Alteiri's *Enhancing the Productivity of Latin American Traditional Peasant Farming Systems Through an Agroecological Approach* for information on agroecology in Latin America.

Agroecological techniques and knowledge played an important role in solving the severe food crisis in Cuba following the dissolution of the Soviet Union. As part of Cuba's urban agricultural movement, agroecology is integral to production in Cuban organopónicos.

Historically, agroecology has had low traction in Africa, as governments, international organisations, extension services and farmers' organisations tended to focus on issues of inputs and outputs as the defining factors to deal with recurrent food crises and chronic malnutrition in the continent. Agrocecology was only a minor proposal from a few, non-governmental, small-scale projects and a sort of "experimental" idea of the Farmer Field Schools programme.

In the early 2000s, when the AIDS pandemic was creating a major rural crisis across Africa, Josep Garí proposed FAO to consider an agroecological approach as the most effective way to empower farmers cope with the impacts of the AIDS pandemic on agriculture and food production: in particular, he proposed agro-biodiversity as a key resource and knowledge for farmers to address the labour and malnutrition crisis. The proposal was rapidly adopted by the Farmer Field Schools scheme across the world, and even presented and translated in China.

Most recently, agroecology has started to permeate projects and discourses on farming and natural-resource management in Africa. In 2011, the 1st encounter of agroecology trainers took place in Zimbabwe and issued the Shashe Declaration.

Most of the historical farming in Madagascar has been conducted by indigenous peoples. The French colonial period disturbed a very small percentage of land area, and even included some useful experiments in Sustainable forestry. Slash-and-burn techniques, a component of some shifting cultivation systems have been practised by natives in Madagascar for centuries. As of 2006 some of the major agricultural products from slash-and-burn methods are wood, charcoal and grass for Zebu grazing. These practices have taken perhaps the greatest toll on land fertility since the end of French rule, mainly due to overpopulation pressures.

Energy crop

An energy crop is a plant grown as a low-cost and low-maintenance harvest used to make biofuels, such as bioethanol, or combusted for its energy content to generate electricity or heat. Energy crops are generally categorized as woody or herbaceous plants; many of the latter are grasses of the family *Graminaceae*.

Commercial energy crops are typically densely planted, high-yielding crop species which are processed to bio-fuel and burnt to generate power. Woody crops such as willowor poplar are widely utilised, as well as temperate grasses such as *Miscanthus* and *Pennisetum purpureum* (both known as elephant grass). If carbohydrate content is desired for the production of biogas, whole-crops such as maize, Sudan grass, millet, white sweet clover and many others, can be made into silage and then converted into biogas.

Through genetic modification and application of biotechnology plants can be manipulated to create greater yields, reduce associated costs and require less water. High energy yield can also be realized with existing cultivars.

Energy generated by burning plants grown for the purpose, often after the dry matter is pelletized. Energy crops are used for firing power plants, either alone or co-fired with other fuels. Alternatively they may be used for heat or combined heat and power (CHP) production.

To cover the increasing requirements of woody biomass, short rotation coppice (SRC) were applied to agricultural sites. Within this cropping systems fast growing tree species like willows and poplars are planted in growing cycles of three to five years. The cultivation of this cultures is dependent on wet soil conditions and could be an alternative for moist field sieds. However, an influence on local water conditions could not be excluded. This indicates that an establishment should exclude the vicinity to vulnerable wetland ecosystems.

Anaerobic digesters or biogas plants can be directly supplemented with energy crops once they have been ensiled into silage. The fastest growing sector of German biofarming has been in the area of "Renewable Energy Crops" on nearly 500,000 ha (1,200,000 acres) of land (2006). Energy crops can also be grown to boost gas yields where feedstocks have a low energy content, such as manures and spoiled grain. It is estimated that the energy yield presently of bioenergy crops converted via silage to methane is about 2 GWh/km^2 (1.8×10^{10} BTU/sq mi). Small mixed cropping enterprises with animals can use a portion of their acreage to grow and convert energy crops and sustain the entire farms energy requirements with about one fifth of the acreage. In Europe and especially Germany, however, this rapid growth has occurred only with substantial government support, as in the German bonus system for renewable energy. Similar developments of integrating crop farming and bioenergy production via silage-methane have been almost entirely overlooked in N. America, where political and structural issues and a huge continued push to centralize energy production has overshadowed positive developments.

European production of biodiesel from energy crops has grown steadily in the last decade, principally focused on rapeseed used for oil and energy. Production of oil/biodiesel from rape covers more than 12,000 km² in Germany alone, and has doubled in the past 15 years. Typical yield of oil as pure biodiesel may be is 100,000 L/km^2 (68,000 US gal/sq mi; 57,000 imp gal/sq mi) or more, making biodiesel crops economically attractive, provided sustainable crop rotations exist that are nutrient-balanced and preventative of the spread of disease such as clubroot.

Energy crops for biobutanol are grasses. Two leading non-food crops for the production of cellulosic bioethanol are switchgrass and giant miscanthus. There has been a preoccupation with cellulosic bioethanol in America as the agricultural structure supporting biomethane is absent in many regions, with no credits or bonus system in place. Consequently, a lot of private money and investor hopes are being pinned on marketable and patentable innovations in enzyme hydrolysis and the like.

Bioethanol also refers to the technology of using principally corn (maize seed) to make ethanol directly through fermentation, a process that under certain field and process conditions can consume as much energy as is the energy value of the ethanol it produces, therefore being non-sustainable. New developments in converting grain stillage (referred to as distillers grain stillage or DGS) into biogas energy looks promising as a means to improve the poor energy ratio of this type of bioethanol process.

Dedicated energy crops are non-food energy crops as giant miscanthus, switchgrass, jatropha, fungi, and algae. Dedicated energy crops are promising cellulose sources that can be sustainably produced in many regions of the United States.

Additionally, the green waste byproducts of food and non-food energy crops can be used to produce various biofuels.

Biofuel

A biofuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter.

Biofuels can be derived directly from plants, or indirectly from agricultural, commercial, domestic, and/or industrial wastes. Renewable biofuels generally involve contemporary carbon fixation, such as those that occur in plants or microalgae through the process of photosynthesis. Other renewable biofuels are made through the use or conversion of biomass (referring to recently living organisms, most often referring to plants or plant-derived materials). This biomass can be converted to convenient energy-containing substances in three different ways: thermal conversion, chemical conversion, and biochemical conversion. This biomass conversion can result in fuel in solid, liquid, or gas form. This new biomass can also be used directly for biofuels.

Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn, sugarcane, or sweet sorghum. Cellulosic biomass, derived from non-food sources, such as trees and grasses, is also being developed as a feedstock for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the United States and in Brazil. Current plant design does not provide for converting the lignin portion of plant raw materials to fuel components by fermentation.

Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe.

In 2010, worldwide biofuel production reached 105 billion liters (28 billion gallons US), up 17% from 2009, and biofuels provided 2.7% of the world's fuels for road transport. Global ethanol fuel production reached 86 billion liters (23 billion gallons US) in 2010, with the United States and Brazil as the world's top producers, accounting together for about 90% of global production. The world's largest biodiesel producer is the European Union, accounting for 53% of all biodiesel production in 2010. As of 2011, mandates for blending biofuels exist in

31 countries at the national level and in 29 states or provinces. The International Energy Agency has a goal for biofuels to meet more than a quarter of world demand for transportation fuels by 2050 to reduce dependence on petroleum and coal. The production of biofuels also led into a flourishing automotive industry, where by 2010, 79% of all cars produced in Brazil were made with a hybrid fuel system of bioethanol and gasoline.

There are various social, economic, environmental and technical issues relating to biofuels production and use, which have been debated in the popular media and scientific journals.

"First-generation" or conventional biofuels are biofuels made from food crops grown on arable land. With this biofuel production generation, food crops are thus explicitly grown for fuel production, and not anything else. The sugar, starch, or vegetable oil obtained from the crops is converted into biodiesel or ethanol, using transesterification, or yeast fermentation.

Second generation biofuels are fuels manufactured from various types of biomass. Biomass is a wide-ranging term meaning any source of organic carbon that is renewed rapidly as part of the carbon cycle. Biomass is derived from plant materials, but can also include animal materials.

Whereas first generation biofuels are made from the sugars and vegetable oils found in arable crops, second generation biofuels are made from lignocellulosic biomass or woody crops, agricultural residues or waste plant material (from food crops but they have already fulfilled their food purpose). The feedstock used to generate second-generation biofuels should grow on lands which cannot be used to effectively grow food and their growing should not consume lots of water or fertilizer. The feedstock sources include grasses, jatropha and other seed crops, waste vegetable oil, municipal solid waste and so forth.

This has both advantages and disadvantages. The advantage is that, unlike with regular food crops, no arable land is used solely for the production of fuel. The disadvantage is that unlike with regular food crops, it may be rather difficult to extract the fuel. For instance, a series of physical and chemical treatments might be required to convert lignocellulosic biomass to liquid fuels suitable for transportation.

From 1978 to 1996, the US NREL experimented with using algae as a biofuels source in the "Aquatic Species Program".A self-published article by Michael

Briggs, at the UNH Biofuels Group, offers estimates for the realistic replacement of all vehicular fuel with biofuels by using algae that have a natural oil content greater than 50%, which Briggs suggests can be grown on algae ponds at wastewater treatment plants. This oil-rich algae can then be extracted from the system and processed into biofuels, with the dried remainder further reprocessed to create ethanol. The production of algae to harvest oil for biofuels has not yet been undertaken on a commercial scale, but feasibility studies have been conducted to arrive at the above yield estimate. In addition to its projected high yield, algaculture – unlike crop-based biofuels – does not entail a decrease in food production, since it requires neither farmland nor fresh water. Many companies are pursuing algae bioreactors for various purposes, including scaling up biofuels production to commercial levels. Prof. Rodrigo E. Teixeira from the University of Alabama in Huntsville demonstrated the extraction of biofuels lipids from wet algae using a simple and economical reaction in ionic liquids.

Similarly to third-generation biofuels, fourth-generation biofuels are made using non-arable land. However, unlike third-generation biofuels, they do not require the destruction of biomass. This class of biofuels includes electrofuels and photobiological solar fuels. Some of these fuels are carbon-neutral. The conversion of crude oil from the plant seeds into useful fuels is called transesterification.

The following fuels can be produced using first, second, third or fourth-generation biofuel production procedures. Most of these can even be produced using two or three of the different biofuel generation procedures.

Biologically produced alcohols, most commonly ethanol, and less commonly propanol and butanol, are produced by the action of microorganisms and enzymes through the fermentation of sugars or starches (easiest), or cellulose (which is more difficult). Biobutanol (also called biogasoline) is often claimed to provide a direct replacement for gasoline, because it can be used directly in a gasoline engine.

Ethanol fuel is the most common biofuel worldwide, particularly in Brazil. Alcohol fuels are produced by fermentation of sugars derived from wheat, corn, sugar beets, sugar cane, molasses and any sugar or starch from which alcoholic beverages such as whiskey, can be made (such as potato and fruit waste, etc.). The ethanol production methods used are enzyme digestion (to release sugars from stored starches), fermentation of the sugars, distillation and drying. The distillation process requires significant energy input for heat (sometimes unsustainable natural gas fossil fuel, but cellulosic biomass such as bagasse, the waste left after sugar cane is pressed to extract its juice, is the most common fuel in Brazil, while pellets, wood chips and also waste heat are more common in Europe) Waste steam fuels ethanol factory where waste heat from the factories also is used in the district heating grid.

Ethanol can be used in petrol engines as a replacement for gasoline; it can be mixed with gasoline to any percentage. Most existing car petrol engines can run on blends of up to 15% bioethanol with petroleum/gasoline. Ethanol has a smaller energy density than that of gasoline; this means it takes more fuel (volume and mass) to produce the same amount of work. An advantage of ethanol (CH_3CH_2OH) is that it has a higher octane rating than ethanol-free gasoline available at roadside gas stations, which allows an increase of an engine's compression ratio for increased thermal efficiency. In high-altitude (thin air) locations, some states mandate a mix of gasoline and ethanol as a winter oxidizer to reduce atmospheric pollution emissions.

Ethanol is also used to fuel bioethanol fireplaces. As they do not require a chimney and are "flueless", bioethanol fires are extremely useful for newly built homes and apartments without a flue. The downsides to these fireplaces is that their heat output is slightly less than electric heat or gas fires, and precautions must be taken to avoid carbon monoxide poisoning.

Corn-to-ethanol and other food stocks has led to the development of cellulosic ethanol. According to a joint research agenda conducted through the US Department of Energy, the fossil energy ratios (FER) for cellulosic ethanol, corn ethanol, and gasoline are 10.3, 1.36, and 0.81, respectively.

Ethanol has roughly one-third lower energy content per unit of volume compared to gasoline. This is partly counteracted by the better efficiency when using ethanol (in a long-term test of more than 2.1 million km, the BEST project found FFV vehicles to be 1–26% more energy efficient than petrol cars, but the volumetric consumption increases by approximately 30%, so more fuel stops are required).

With current subsidies, ethanol fuel is slightly cheaper per distance traveled in the United States.

Biodiesel is the most common biofuel in Europe. It is produced from oils or fats using transesterification and is a liquid similar in composition to fossil/mineral diesel. Chemically, it consists mostly of fatty acid methyl (or ethyl) esters (FAMEs). Feedstocks for biodiesel include animal fats, vegetable oils, soy, rapeseed, jatropha, mahua, mustard, flax, sunflower, palm oil, hemp, field pennycress, *Pongamia pinnata* and algae. Pure biodiesel (B100, also known as "neat" biodiesel) currently reduces emissions with up to 60% compared to diesel Second generation B100.

Biodiesel can be used in any diesel engine when mixed with mineral diesel. In some countries, manufacturers cover their diesel engines under warranty for B100 use, although Volkswagen of Germany, for example, asks drivers to check by telephone with the VW environmental services department before switching to B100. B100 may become more viscous at lower temperatures, depending on the feedstock used. In most cases, biodiesel is compatible with diesel engines from 1994 onwards, which use 'Viton' (by DuPont) synthetic rubber in their mechanical fuel injection systems. Note however, that no vehicles are certified for using pure biodiesel before 2014, as there was no emission control protocol available for biodiesel before this date.

Electronically controlled 'common rail' and 'unit injector' type systems from the late 1990s onwards may only use biodiesel blended with conventional diesel fuel. These engines have finely metered and atomized multiple-stage injection systems that are very sensitive to the viscosity of the fuel. Many current-generation diesel engines are made so that they can run on B100 without altering the engine itself, although this depends on the fuel rail design. Since biodiesel is an effective solvent and cleans residues deposited by mineral diesel, engine filters may need to be replaced more often, as the biofuel dissolves old deposits in the fuel tank and pipes. It also effectively cleans the engine combustion chamber of carbon deposits, helping to maintain efficiency. In many European countries, a 5% biodiesel blend is widely used and is available at thousands of gas stations. Biodiesel is also an oxygenated fuel, meaning it contains a reduced amount of carbon and higher hydrogen and oxygen content than fossil diesel. This improves the combustion of biodiesel and reduces the particulate emissions from unburnt carbon. However, using pure biodiesel may increase NO_x-emissions .

Biodiesel is also safe to handle and transport because it is non-toxic and biodegradable, and has a high flash point of about 300 °F (148 °C) compared to petroleum diesel fuel, which has a flash point of 125 °F (52 °C).

In the USA, more than 80% of commercial trucks and city buses run on diesel. The emerging US biodiesel market is estimated to have grown 200% from 2004 to 2005. "By the end of 2006 biodiesel production was estimated to increase fourfold [from 2004] to more than" 1 billion US gallons (3,800,000 m^3).

In France, biodiesel is incorporated at a rate of 8% in the fuel used by all French diesel vehicles. Avril Group produces under the brand Diester, a fifth of 11 million tons of biodiesel consumed annually by the European Union. It is the leading European producer of biodiesel.

Methanol is currently produced from natural gas, a non-renewable fossil fuel. In the future it is hoped to be produced from biomass as biomethanol. This is technically feasible, but the production is currently being postponed for concerns of Jacob S. Gibbs and Brinsley Coleberd that the economic viability is still pending. The methanol economy is an alternative to the hydrogen economy, compared to today's hydrogen production from natural gas.

Butanol (C_4H_9OH) is formed by ABE fermentation (acetone, butanol, ethanol) and experimental modifications of the process show potentially high net energy gains with butanol as the only liquid product. Butanol will produce more energy and allegedly can be burned "straight" in existing gasoline engines (without modification to the engine or car), and is less corrosive and less water-soluble than ethanol, and could be distributed via existing infrastructures. DuPont and BP are working together to help develop butanol. *Escherichia coli* strains have also been successfully engineered to produce butanol by modifying their amino acid metabolism.

Green diesel is produced through hydrocracking biological oil feedstocks, such as vegetable oils and animal fats. Hydrocracking is a refinery method that uses elevated temperatures and pressure in the presence of a catalyst to break down larger molecules, such as those found in vegetable oils, into shorter hydrocarbon chains used in diesel engines. It may also be called renewable diesel, hydrotreated vegetable oil or hydrogen-derived renewable diesel. Green diesel has the same chemical properties as petroleum-based diesel. It does not require new engines, pipelines or infrastructure to distribute and use, but has not been produced at a cost that is competitive with petroleum. Gasoline versions are also being developed. Green diesel is being developed in Louisiana and Singapore by ConocoPhillips, Neste Oil, Valero, Dynamic Fuels, and Honeywell UOP as well as Preem in Gothenburg, Sweden, creating what is known as Evolution Diesel.

In 2013 UK researchers developed a genetically modified strain of *E. coli*, which could transform glucose into biofuel gasoline that does not need to be blended. Later in 2013 UCLA researchers engineered a new metabolic pathway to bypass glycolysis and increase the rate of conversion of sugars into biofuel, while KAIST researchers developed a strain capable of producing short-chain alkanes, free fatty acids, fatty esters and fatty alcohols through the fatty acyl (acyl carrier protein (ACP)) to fatty acid to fatty acyl-CoA pathway *in vivo*. It is believed that in the future it will be possible to "tweak" the genes to make gasoline from straw or animal manure.

Straight unmodified edible vegetable oil is generally not used as fuel, but lower-quality oil has been used for this purpose. Used vegetable oil is increasingly being processed into biodiesel, or (more rarely) cleaned of water and particulates and then used as a fuel.

As with 100% biodiesel (B100), to ensure the fuel injectors atomize the vegetable oil in the correct pattern for efficient combustion, vegetable oil fuel must be heated to reduce its viscosity to that of diesel, either by electric coils or heat exchangers. This is easier in warm or temperate climates. MAN B&W Diesel, Wärtsilä, and Deutz AG, as well as a number of smaller companies, such as Elsbett, offer engines that are compatible with straight vegetable oil, without the need for after-market modifications.

Vegetable oil can also be used in many older diesel engines that do not use common rail or unit injection electronic diesel injection systems. Due to the design of the combustion chambers in indirect injectionengines, these are the best engines for use with vegetable oil. This system allows the relatively larger oil molecules more time to burn. Some older engines, especially Mercedes, are driven experimentally by enthusiasts without any conversion, a handful of drivers have experienced limited success with earlier pre-"Pumpe Duse" VW TDI engines and other similar engines with direct injection. Several companies, such as Elsbett or Wolf, have developed professional conversion kits and successfully installed hundreds of them over the last decades.

Oils and fats can be hydrogenated to give a diesel substitute. The resulting product is a straight-chain hydrocarbon with a high cetane number, low in aromatics and sulfur and does not contain oxygen. Hydrogenated oils can be blended with diesel in all proportions. They have several advantages over biodiesel, including good performance at low temperatures, no storage stability problems and no susceptibility to microbial attack.

Bioethers (also referred to as fuel ethers or oxygenated fuels) are cost-effective compounds that act as octane rating enhancers."Bioethers are produced by the reaction of reactive iso-olefins, such as iso-butylene, with bioethanol." Bioethers are created by wheat or sugar beet. They also enhance engine performance, whilst significantly reducing engine wear and toxic exhaust emissions. Though bioethers are likely to replace petroethers in the UK, it is highly unlikely they will become a fuel in and of itself due to the low energy density. Greatly reducing the amount of ground-level ozone emissions, they contribute to air quality.

When it comes to transportation fuel there are six ether additives: dimethyl ether (DME), diethyl ether (DEE), methyl teritiary-butyl ether (MTBE), ethyl *ter*-butyl ether (ETBE), t*er*-amyl methyl ether (TAME), and *ter*-amyl ethyl ether (TAEE).

The European Fuel Oxygenates Association (EFOA) credits methyl Ttertiary-butyl ether (MTBE) and ethyl ter-butyl ether (ETBE) as the most commonly used ethers in fuel to replace lead. Ethers were introduced in Europe in the 1970s to replace the highly toxic compound. Although Europeans still use bio-ether additives, the US no longer has an oxygenate requirement therefore bio-ethers are no longer used as the main fuel additive.

Biogas is methane produced by the process of anaerobic digestion of organic material by anaerobes. It can be produced either from biodegradable waste materials or by the use of energy crops fed into anaerobic digesters to supplement gas yields. The solid byproduct, digestate, can be used as a biofuel or a fertilizer.

Biogas can be recovered from mechanical biological treatment waste processing systems. Landfill gas, a less clean form of biogas, is produced in landfills through naturally occurring anaerobic digestion. If it escapes into the atmosphere, it is a potential greenhouse gas.

Farmers can produce biogas from manure from their cattle by using anaerobic digesters.

Syngas, a mixture of carbon monoxide, hydrogen and other hydrocarbons, is produced by partial combustion of biomass, that is, combustion with an amount of oxygen that is not sufficient to convert the biomass completely to carbon dioxide and water. Before partial combustion, the biomass is dried, and sometimes pyrolysed. The resulting gas mixture, syngas, is more efficient than direct combustion of the original biofuel; more of the energy contained in the fuel is extracted.

Syngas may be burned directly in internal combustion engines, turbines or high-temperature fuel cells. The wood gas generator, a wood-fueled gasification reactor, can be connected to an internal combustion engine.

Syngas can be used to produce methanol, DME and hydrogen, or converted via the Fischer-Tropsch process to produce a diesel substitute, or a mixture of alcohols that can be blended into gasoline. Gasification normally relies on temperatures greater than 700 °C.

Lower-temperature gasification is desirable when co-producing biochar, but results in syngas polluted with tar.

Examples include wood, sawdust, grass trimmings, domestic refuse, charcoal, agricultural waste, nonfood energy crops, and dried manure.

When solid biomass is already in a suitable form (such as firewood), it can burn directly in a stove or furnace to provide heat or raise steam. When solid biomass is in an inconvenient form (such as sawdust, wood chips, grass, urban waste wood, agricultural residues), the typical process is to densify the biomass. This process includes grinding the raw biomass to an appropriate particulate size (known as hogfuel), which, depending on the densification type, can be from 1 to 3 cm (0.4 to 1.2 in), which is then concentrated into a fuel product. The current processes produce wood pellets, cubes, or pucks. The pellet process is most common in Europe, and is typically a pure wood product. The other types of densification are larger in size compared to a pellet and are compatible with a broad range of input feedstocks. The resulting densified fuel is easier to transport and feed into thermal generation systems, such as boilers.

Sawdust, bark and chips are already used for decades for fuel in industrial processes; examples include the pulp and paper industry and the sugar cane industry. Boilers in the range of 500,000 lb/hr of steam, and larger, are in routine operation, using grate, spreader stoker, suspension burning and fluid bed combustion. Utilities generate power, typically in the range of 5 to 50 MW, using locally available fuel. Other industries have also installed wood waste fueled boilers and dryers in areas with low-cost fuel.

One of the advantages of solid biomass fuel is that it is often a byproduct, residue or waste-product of other processes, such as farming, animal husbandry and forestry. In theory, this means fuel and food production do not compete for resources, although this is not always the case.

A problem with the combustion of solid biomass fuels is that it emits considerable amounts of pollutants, such as particulates and polycyclic aromatic hydrocarbons. Even modern pellet boilers generate much more pollutants than oil or natural gas boilers. Pellets made from agricultural residues are usually worse than wood pellets, producing much larger emissions of dioxins and chlorophenols.

A derived fuel is biochar, which is produced by biomass pyrolysis. Biochar made from agricultural waste can substitute for wood charcoal. As wood stock becomes scarce, this alternative is gaining ground. In eastern Democratic Republic of Congo, for example, biomass briquettes are being marketed as an alternative to charcoal to protect Virunga National Park from deforestation associated with charcoalproduction.

There are international organizations such as IEA Bioenergy, established in 1978 by the OECD International Energy Agency (IEA), with the aim of improving cooperation and information exchange between countries that have national programs in bioenergy research, development and deployment.
The UN International Biofuels Forum is formed
by Brazil, China, India, Pakistan, South Africa, the United States and the European Commission. The world leaders in biofuel development and use are Brazil, the United States, France, Sweden and Germany. Russia also has 22% of world's forest, and is a big biomass (solid biofuels) supplier. In 2010, Russian pulp and paper maker, Vyborgskaya Cellulose, said they would be producing pellets that can be used in heat and electricity generation from its plant in Vyborg by the end of the year. The plant will eventually produce about 900,000 tons of pellets per year, making it the largest in the world once operational.

Biofuels currently make up 3.1% of the total road transport fuel in the UK or 1,440 million litres. By 2020, 10% of the energy used in UK road and rail transport must come from renewable sources – this is the equivalent of replacing 4.3 million tonnes of fossil oil each year. Conventional biofuels are likely to produce between 3.7 and 6.6% of the energy needed in road and rail transport, while advanced biofuels could meet up to 4.3% of the UK's renewable transport fuel target by 2020.

Biofuels are similar to fossil fuels in that biofuels contribute to air pollution. Burning produces carbon dioxide, airborne carbon particulates, carbon monoxide and nitrous oxides. The WHO estimates 3.7 million premature deaths worldwide in 2012 due to air pollution. Brazil burns significant amounts of ethanol biofuel. Gas chromatograph studies were performed of ambient air in São Paulo, Brazil, and compared to Osaka, Japan, which does not burn ethanol fuel. Atmospheric Formaldehyde was 160% higher in Brazil, and Acetaldehyde was 260% higher.

The Environmental Protection Agency has acknowledged in April 2007 that the increased use of bio-ethanol will lead to worse air quality. The total emissions of air pollutants such as nitrogen oxides will rise due the growing use of bio-ethanol. There is an increase in carbon dioxide from the burning of fossil fuels to produce the biofuels as well as nitrous oxide from the soil, which has most likely been treated with nitrogen fertilizer. Nitrous oxide is known to have a greater impact on the atmosphere in relation to global warming, as it is also an ozone destroyer.

There are various social, economic, environmental and technical issues with biofuel production and use, which have been discussed in the popular media and scientific journals. These include: the effect of moderating oil prices, the "food vs fuel" debate, food prices, poverty reduction potential, energy ratio, energy requirements, carbon emissions levels, sustainable biofuel production, deforestation and soil erosion, loss of biodiversity, impact on water resources, the possible modifications necessary to run the engine on biofuel, as well as energy balance and efficiency. The International Resource Panel, which provides independent scientific assessments and expert advice on a variety of resource-related themes, assessed the issues relating to biofuel use in its first report *Towards sustainable production and use of resources: Assessing Biofuels*. "Assessing Biofuels" outlined the wider and interrelated factors that need to be considered when deciding on the relative merits of pursuing one biofuel over another. It concluded that not all biofuels perform equally in terms of their impact on climate, energy security and ecosystems, and suggested that environmental and social impacts need to be assessed throughout the entire life-cycle.

Another issue with biofuel use and production is the US has changed mandates many times because the production has been taking longer than expected. The

Renewable Fuel Standard (RFS) set by congress for 2010 was pushed back to at best 2012 to produce 100 million gallons of pure ethanol .

In the EU, the revised renewable energy directive calls for a complete ban on first-generation biofuels. Particularly fuels made from such oils such as palm oil and soy oil are being targeted.

Many of the biofuels that were being supplied in 2008 (using the first-generation biofuel production procedure) have been criticised for their adverse impacts on the natural environment, food security, and land use. In 2008, the Nobel-prize winning chemist Paul J. Crutzen published findings that the release of nitrous oxide (N_2O) emissions in the production of biofuels means that overall they contribute more to global warming than the fossil fuels they replace. In 2008, the challenge was to support biofuel development, including the development of new cellulosic technologies, with responsible policies and economic instruments to help ensure that biofuel commercialization is sustainable. Responsible commercialization of biofuels represented an opportunity to enhance sustainable economic prospects in Africa, Latin America and Asia. Now, biofuels in the form of liquid fuels derived from plant materials are entering the market, driven by the perception that they reduce climate gas emissions, and also by factors such as oil price spikes and the need for increased energy security.

According to the Rocky Mountain Institute, sound biofuel production practices would not hamper food and fibre production, nor cause water or environmental problems, and would enhance soil fertility. The selection of land on which to grow the feedstocks is a critical component of the ability of biofuels to deliver sustainable solutions. A key consideration is the minimisation of biofuel competition for prime cropland.

Some scientists have expressed concerns about land-use change in response to greater demand for crops to use for biofuel and the subsequent carbon emissions. The payback period, that is, the time it will take biofuels to pay back the carbon debt they acquire due to land-use change, has been estimated to be between 100 and 1000 years, depending on the specific instance and location of land-use change. However, no-till practices combined with cover-crop practices can reduce the payback period to three years for grassland conversion and 14 years for forest conversion.

A study conducted in the Tocantis State, in northern Brazil, found that many families were cutting down forests in order to produce two conglomerates of oilseed plants, the J. curcas (JC group) and the R. communis (RC group). This region is composed of 15% Amazonian rainforest with high biodiversity, and 80% Cerrado forest with lower biodiversity. During the study, the farmers that planted the JC group released over 2193 Mg CO_2, while losing 53-105 Mg CO_2 sequestration from deforestation; and the RC group farmers released 562 Mg CO_2, while losing 48-90 Mg CO_2 to be sequestered from forest depletion. The production of these types of biofuels not only led into an increased emission of carbon dioxide, but also to lower efficiency of forests to absorb the gases that these farms were emitting. This has to do with the amount of fossil fuel the production of fuel crops involves. In addition, the intensive use of monocropping agriculture requires large amounts of water irrigation, as well as of fertilizers, herbicides and pesticides. This does not only lead to poisonous chemicals to disperse on water runoff, but also to the emission of nitrous oxide (NO_2) as a fertilizer byproduct, which is three hundred times more efficient in producing a greenhouse effect than carbon dioxide (CO_2).

Converting rainforests, peatlands, savannas, or grasslands to produce food crop–based biofuels in Brazil, Southeast Asia, and the United States creates a “biofuel carbon debt” by releasing 17 to 420 times more CO_2 than the annual greenhouse gas (GHG) reductions that these biofuels would provide by displacing fossil fuels. Biofuels made from waste biomass or from biomass grown on abandoned agricultural lands incur little to no carbon debt.

In addition to crop growth requiring water, biofuel facilities require significant process water.

Research is ongoing into finding more suitable biofuel crops and improving the oil yields of these crops. Using the current yields, vast amounts of land and fresh water would be needed to produce enough oil to completely replace fossil fuel usage. It would require twice the land area of the US to be devoted to soybean production, or two-thirds to be devoted to rapeseed production, to meet current US heating and transportation needs.

Specially bred mustard varieties can produce reasonably high oil yields and are very useful in crop rotation with cereals, and have the added benefit that the meal left over after the oil has been pressed out can act as an effective and biodegradable pesticide.

The NFESC, with Santa Barbara-based Biodiesel Industries, is working to develop biofuels technologies for the US navy and military, one of the largest diesel fuel users in the world. A group of Spanish developers working for a company called Ecofasa announced a new biofuel made from trash. The fuel is created from general urban waste which is treated by bacteria to produce fatty acids, which can be used to make biofuels. Before its shutdown, Joule Unlimited was attempting to make cheap ethanol and biodiesel from a genetically modified photosynthetic bacterium.

As the primary source of biofuels in North America, many organizations are conducting research in the area of ethanol production. The National Corn-to-Ethanol Research Center (NCERC) is a research division of Southern Illinois University Edwardsville dedicated solely to ethanol-based biofuel research projects. On the federal level, the USDA conducts a large amount of research regarding ethanol production in the United States. Much of this research is targeted toward the effect of ethanol production on domestic food markets. A division of the U.S. Department of Energy, the National Renewable Energy Laboratory (NREL), has also conducted various ethanol research projects, mainly in the area of cellulosic ethanol.

Cellulosic ethanol commercialization is the process of building an industry out of methods of turning cellulose-containing organic matter into fuel. Companies, such as Iogen, POET, and Abengoa, are building refineries that can process biomass and turn it into bioethanol. Companies, such as Diversa, Novozymes, and Dyadic, are producing enzymes that could enable a cellulosic ethanol future. The shift from food crop feedstocks to waste residues and native grasses offers significant opportunities for a range of players, from farmers to biotechnology firms, and from project developers to investors.

As of 2013, the first commercial-scale plants to produce cellulosic biofuels have begun operating. Multiple pathways for the conversion of different biofuel feedstocks are being used. In the next few years, the cost data of these technologies operating at commercial scale, and their relative performance, will become available. Lessons learnt will lower the costs of the industrial processes involved.

In parts of Asia and Africa where drylands prevail, sweet sorghum is being investigated as a potential source of food, feed and fuel combined. The crop is particularly suitable for growing in arid conditions, as it only extracts one seventh of the water used by sugarcane. In India, and other places, sweet sorghum stalks are used to produce biofuel by squeezing the juice and then fermenting into ethanol.

A study by researchers at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) found that growing sweet sorghum instead of grain sorghum could increase farmers incomes by US$40 per hectare per crop because it can provide fuel in addition to food and animal feed. With grain sorghum currently grown on over 11 million hectares (ha) in Asia and on 23.4 million ha in Africa, a switch to sweet sorghum could have a considerable economic impact.

Several groups in various sectors are conducting research on *Jatropha curcas*, a poisonous shrub-like tree that produces seeds considered by many to be a viable source of biofuels feedstock oil. Much of this research focuses on improving the overall per acre oil yield of Jatropha through advancements in genetics, soil science, and horticultural practices.

SG Biofuels, a San Diego-based jatropha developer, has used molecular breeding and biotechnology to produce elite hybrid seeds that show significant yield improvements over first-generation varieties. SG Biofuels also claims additional benefits have arisen from such strains, including improved flowering synchronicity, higher resistance to pests and diseases, and increased cold-weather tolerance.

Plant Research International, a department of the Wageningen University and Research Centre in the Netherlands, maintains an ongoing Jatropha Evaluation Project that examines the feasibility of large-scale jatropha cultivation through field and laboratory experiments. The Center for Sustainable Energy Farming (CfSEF) is a Los Angeles-based nonprofit research organization dedicated to jatropha research in the areas of plant science, agronomy, and horticulture. Successful exploration of these disciplines is projected to increase jatropha farm production yields by 200-300% in the next 10 years.

A group at the Russian Academy of Sciences in Moscow, in a 2008 paper, stated they had isolated large amounts of lipids from single-celled fungi and turned it into biofuels in an economically efficient manner. More research on this fungal species, *Cunninghamella japonica*, and others, is likely to appear in the near future. The recent discovery of a variant of the fungus *Gliocladium roseum* (later renamed Ascocoryne sarcoides) points toward the production of so-called myco-diesel from cellulose. This organism was recently discovered in the rainforests of northern Patagonia, and has the unique capability of converting cellulose into medium-length hydrocarbons typically found in diesel fuel. Many other fungi that can degrade cellulose and other polymers have been observed to produce molecules that are currently being engineered using organisms from other kingdoms, suggesting that fungi may play a large role in the bio-production of fuels in the future .

Microbial gastrointestinal flora in a variety of animals have shown potential for the production of biofuels. Recent research has shown that TU-103, a strain of *Clostridium* bacteria found in Zebra feces, can convert nearly any form of cellulose into butanol fuel. Microbes in panda waste are being investigated for their use in creating biofuels from bamboo and other plant materials. There has also been substantial research into the technology of using the gut microbiomes of wood-feeding insects for the conversion of lignocellulotic material into biofuel.

The development of Brazilian agriculture

The strategic importance of the agricultural sector to Brazilian economic growth has been clear since the first colonial ventures in the early 16th century . Until the 1930s, the Brazilian economy was strongly based on agricultural products destined for foreign markets, and two main classes of product (coffee and some other agricultural commodities (rubber, cocoa, cotton)) accounted for over 55% of the exports until the 1960s . These externally oriented expansions, focused on a few products, were eventually translated into short-lived periods of boom and bust leading to high volatility in economic growth (compared with developed countries) and to considerable external vulnerability . By the end of the 1990s, commodities were still important for Brazilian exports, but the two main products of the 1990s, soybean and iron ore, represented 10% of total exports .

Ironically, in spite of the role of agriculture in the Brazilian economy, the country systematically received food aid from abroad until the 1960s, and even up to the 1980s, Brazil was still a large food importer. The traditional agriculture that prevailed in Brazil until the 1970s, whose growth mostly occurred on the extensive margin was progressively transformed during the following decades into a modern and strongly competitive agriculture based on science .

To a great extent, these huge changes in Brazilian agriculture occurred in response to a strong demand, prompted by the government-led industrialization process that took place in Brazil from the 1960s to the early 1980s. This industrialization period was associated with a growing population with higher income and to a rapid process of urbanization. The increased opportunity cost of labor for farmers and extensive migration from rural areas to cities additionally led to a favorable environment for agricultural growth and modernization .

The ambitious industrialization policy aimed at reducing imports was based on exchange controls, on multiple exchange-rate systems to favor import of capital goods, and on subsidized interest rates for loans for the capital goods industry . Along with the associated structural transformation that took place in the primary production sector, the industry and service sectors directly linked to agriculture, given their high backward and forward linkages, became two of the worlds largest and most competitive industries.

Economic policy also promoted import of consumer goods and investments in energy and transport infrastructure. Investments in federal and state highway systems were key to agriculture expansion, initially in terms of area (from the

1950s to 1970s), and then in terms of increased productivity (transport of modern inputs and agricultural products to markets in the cities).

At that time of government-led industrialization, agricultural policies were subordinate to the major goal of industrialization . Government priorities were being focused on cities. The purchasing power of urban salaries was further favored by investments in urban infrastructure, such as housing and health, and by safeguarding of salaries. Food prices were kept artificially low to avoid pressure on urban salaries. In addition to the expansion of agricultural output, agricultural exports were diversified, increasingly providing a means of capital goods imports for the rising national industry .

Economically, the industrialization policies were translated into an increase in the share of industrys gross domestic product (GDP) in the countrys GDP . Politically, the industrialization policy shifted the power from the rural areas to the cities, transforming Brazil into a progressive urban society .

After the 1990s, the urbanization process lost impetus. That was partly because the ruralurban cycle was almost completed in the south, southeast and midwestern regions of the country , but also because of the low economic growth rates during the 1980s and the 1990s, which possibly weakened the attractiveness of cities .

In summary, the rapid industrialization process that took place in Brazil between the 1960s and 1980s led to an important transformation in the country, which imposed pressures on the agricultural sector. The advantages granted to industrialization that discriminated against agriculture required, among other things, that food prices were kept artificially low to avoid wage inflation through pressure on urban salaries. In addition, migration from rural to urban areas was fuelled by better wages in the cities, a consequence of the growing industrialization that was taking place in the country. Political power also shifted from the rural areas to the cities. As a result, opportunities for agribusiness exports were identified as a means to generate funds to finance imports of technology and capital assets for the emerging industrial sector.

However, in spite of these pressures on the agricultural sector, it became clear that opportunities for agricultural expansion in traditional areas were limited. This scenario required a strategy to transform traditional agriculture into a modern, vigorous, and dynamic sector, based on scientific advances. Thus, it became clear that there was a need not only to increase productivity in already opened areas but also to transform the unproductive Cerrado (the savannah-like biome in Brazil) into productive land in order to guarantee increased agricultural production and to ensure food for the growing urban population at affordable prices.

Three policies played a central role in the process of agricultural modernization: 1) the availability of subsidized financial credit, mainly for capital financing and for purchasing modern inputs; 2) the rural extension; and 3) the provision of support for agricultural research (the National Agricultural Research System, coordinated by the Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuria; Embrapa)).

Embrapa is a case of successful institutional innovation. It is a public corporation model of organization, spatially decentralized but operating at national level, with specialized research units that invest in the professional development of its personnel (training and remuneration of human resources) and promote a vision of agriculture based on science and technology. Moreover, from the beginning, the organization has always been result-oriented. Embrapa was founded on two basic tenets: 1) a focused research model, concentrating on products and areas of fundamental importance for the development of the country, and constituting an objective way of identifying research priorities; and 2) development of its human resource capacity, based on strong training programs in centers of excellence around the world .

From the mid-1990s onwards, macroeconomic stability, better relative prices for agricultural commodities in the world markets, and the maturation of tropical agricultural technologies that had been generated in the preceding two decades provided the basis for a new era in Brazilian agribusiness. The sector moved forward rapidly from a traditionally based agricultural system to one based on science.

As a result, between December 1977 and January 2007, the domestic price for food in Brazil, in real terms, dropped at a monthly average rate of 2% . In fact, the price of a representative food basket in November 2011 represented, in real terms, around 50% of the price paid by consumers in January 1975 .

In the period covering 1978 to 2011, poultry production increased from 1.096 million tonnes to 12.928 million tonnes; pork production increased from 1.060 million tonnes to 3.384 million tonnes; and beef production increased from 2.114 million tonnes to 9.184 million tonnes. During the same period, yearly growth rates recorded for beef, poultry, and pork were, respectively, 4.70%, 8.02%, and 3.70%.

Milk production also increased markedly, from 11.16 billion liters in 1980 to 30.3 billion liters in 2009.

Another important characteristic of the expansion of production in Brazilian agriculture was its focus on productivity gains. During the period 1950 to 2006, productivity gains accounted for 79% of the growth in beef production in Brazil and supported a land-saving effect equivalent to 525 million hectares. Therefore, without this land-saving effect, an additional pasture area 25% larger than the Amazon biome in Brazil would have been needed to meet 2006 levels of Brazilian beef production . During this same period, production of Brazilian grain, oilseeds, and sugarcane provided an additional land-saving effect of 78 million hectares .

The total factor productivity (TFP) for Brazilian agriculture increased steadily over the 36years from 1970 to 2006. Compared with 1970 (index 100), TFP increased by 124%, production rose by 243%, and inputs grew by 53%. Gains in productivity represented 65% of agricultural output in the period 1970 to 2006, and inputs accounted for 35% .

The three major determinants of agricultural productive capacity are human capital, technology generation and dissemination, and adequacy of natural resources and weather conditions .

The need for science-based technologies, given the changing environment in response to climate change and to the evolving socioeconomic context, means that capacity building and strengthening in Brazilian agriculture will be of crucial importance in the coming decades. For this to be realized education should be significantly improved (around 50% of rural workers have up to only four years of education; . Knowledge and technology needs to be generated by organized (public and private) research and transferred to end users through the research system, which adapts technologies to the specific needs of the country and regions .

Brazil has an abundance of natural resources, which have been protected by the enormous land-saving effects provided by the productivity gains in Brazilian agriculture over the past decades. Weather conditions (rainfall, radiation, temperature) are conducive to at least one good crop per year, and in many grain-producing regions, they are favorable for two and sometimes even three crops per year. Soils generally do not have physical problems. Technologies delivered over the past 40years have removed the constraints imposed by the poor acid soils of the Cerrado. Three examples of notable technologies that transformed Brazilian agriculture over the past four decades are discussed below.

Soybean varieties that require no nitrogen have been selected for use in Brazil , and yields of up to 6 tonnes/hectare have already been recorded . Re-inoculating soybean crops with *Bradyrhizobium*species, even in soils with high *Bradyrhizobium* population, is a recommended practice .

There is still some debate on the actual amount of nitrogen that can be acquired from biological nitrogen fixation (BNF) in non-leguminous crops associated BNF and, hence, on the overall BNF contribution to fertilizer-N economy in these agricultural systems. For example, there is evidence that it is possible to obtain up to 50kg of nitrogen per hectare per year from BNF in tropical pastures (using *Brachiaria spp. and Panicum maximum*); however, it is necessary to access such contributions in pastures under grazing conditions . Positive results in replacing part of the requirement for nitrogen fertilizers with BNF have also been reported with other graminaceous plants, such as rice , and in bio-energy crops such as sugarcane .

The development of Brazilian Cerrado into agricultural land required a large portfolio of technologies, which have made the region one of the top grain and beef-producing regions in the world. Technology was the main driving force behind the development of agriculture in the Brazilian Cerrado, and included improving the soil to the standard required by agricultural use, producing new crop and pasture varieties, and improving the productivity of farm animals, mainly beef and dairy cattle.

The most important discoveries were related to improvement of soil fertility , BNF , new plant varieties and hybrids (see section on grain in Albuquerque and Silva), use of no-tillage systems and integrated crop and livestock systems . The technologies applied were compatible with sustainable production, and took into account human and environmental needs. As discussed earlier, the increased yields have saved millions of hectares of native vegetation and tropical forests .

Some recently developed technologies are applicable to all crops, such as fertilization practices and no-tillage systems. Tailoring technologies to take into account regional variation, individual farms, and relative prices is required. Other technologies, however, are cropspecific, such as new crop varieties, or strategies to control diseases, pests, and weeds. Sustainable agriculture may be seen as a package of technologies, some of which fit several crops, and others which are specific to particular crops.

In 1970, grain production in the Cerrado was 8 million tonnes. By 2006, the production amounted to 48.2 million tonnes, a noteworthy annual growth rate of 5.2% (a six-fold increase) in 36years . Until 1980, grain production in the Cerrado followed an extensive margin. After that, production increased at a much faster rate than in the rest of Brazil, and the contribution of the Cerrado to total grain production increased from 35.4% in 1970 to 49.2% in 2006 . In other words, the Cerrado biome in Brazil, which occupies roughly 25% of the countrys territory, accounted for nearly 50% of grain production. This is certainly a notable feat, considering the acid, low-fertility nature of the soils in the region.

Apart from rice and edible beans, all other agricultural products analyzed in this section are being displaced into the Cerrado. Edible bean crops have remained stable but rice which was used in the agricultural frontier expansion in the Cerrado in the 1970s and 1980s is now concentrated in irrigated land in the southern part of Brazil or regions in the Cerrado not prone to extreme conditions. The most notable cases of crop expansion in the region are soybean and cotton.

In the period from 1970 to 1990, when the Cerrado was being opened up to agriculture, land was also being brought into agricultural production. Consequently, in the 19701980 period, the increased agricultural land area accounted for the largest share of increased production. In the after periods up to 2006, most of the increase in production was due to yield increases; in the 19702006 period, yield gains in the Cerrado accounted for 61.4% of agricultural production variation .

The contribution of yield improvements to rice and beans production is notable . Improvements in maize production throughout the past four decades and in coffee production in the past two decades were largely based on yield gains. The contribution of yield increases to cotton production varied considerably, and in the case of soybean, most of the production expansion was explained by area increase. It should be noted that recent (1996 to 2006) expansion of cropping areas in the Cerrado region (especially for soybean in the north and sugarcane in the south), is mainly a result of conversion of pasture to agricultural land.

Cerrado beef production totaled 0.83 million tons in 1975. Since then, it has had a noticeable annual growth rate of 4.1%, attaining 2.89 million tons in 2006. Beef production from the Cerrado, as a percentage of Brazils total production, exceeded 38% in all agricultural census years from 1975 to 2006, and was as high as 53.1% .

Milk production from the Cerrado averaged 2.2 million liters in 1970, but steadily increased by 3.6% per year to reach 8.1 million liters in 2006. In the period 1975 to

2006, milk production in the Cerrado represented between 37% and 45% of total Brazilian milk production .

The growth dynamics of the Cerrados beef and milk production have been notable. From 1985, productivity increases have accounted for the entire expansion of beef production in the biome . Martha *et al.* investigated the contribution of the components of productivity in Brazil and reported that animal performance accounted for 65%, whereas stocking rates were responsible for 35% of the gains.

Increased productivity accounted for 43% to 98% of the milk production increases over the 1975 to 1996 period .In the past decade (1985 to 1996), yield accounted for 98% of the growth in production.

In summary, the significant productivity gains in animal production in the Cerrado were achieved as a result of the continual incorporation of technology. These productivity gains in beef and milk production provided land-saving effects that played an obvious pivotal role in making land available for crop expansion, thus minimizing pressure on natural resources.

Integrated croplivestock systems are an example of a resource-saving technology, and it has received much attention from researchers worldwide . The main reported agronomic/environmental benefits of these systems are: improved chemical, physical and biological properties of the soil; reduction in disease, pest and weed outbreaks; and higher crop and animal productivity . As a result of improved herbage quality (nutritive value and consumption), integrated croplivestock systems can additionally contribute to lower methane emissions per unit of live weight gain for grazing animals.

As summarized by Vilela *et al.* , the adoption of these mixed systems in the Brazilian Cerrado region has been associated with: 1) a 15% increase in the soil organic matter content compared with the native Cerrado; 2) up to 90% increase in apparent phosphorus use efficiency in corn-soybean rotation; 3) soybean yield gains exceeding 10% using rotation with productive pastures compared with soybean in monoculture; and 4) up to three (cow-calf phase) and four-fold (rearing/finishing phase) increase in animal productivity for grazing cattle compared with traditional, extensive pastoral beef systems.

The potential economic benefits of these integrated croplivestock systems may reflect economies of scope (reduced cost associated with producing multiple outputs) or the risk-reducing effects of diversification. The benefits of crop rotations (including pasture) may also include reduced yield variability and overall higher yields. Accurate measurement of interactions between crop and animal (pasture) components to allow for improved and unbiased decision-making is a key step to be pursued .

In Brazil, the high demand for capital in these mixed systems is perceived as a major constraint on their widespread adoption. High demand for capital also increases the financial risk of integrated croplivestock systems, which needs to be weighed against potentially decreased production risks. The design of innovative financing mechanisms will be essential to foster and accelerate large-scale adoption of the integrated croplivestock system technology .

In this final section we would like to explore two key issues that will play a pivotal role in Brazilian agriculture in the future. An important characteristic of Brazilian agriculture has been its ability to expand production with the involvement of farmers from small, medium and large farms. However, in Brazil, land accounts for about 20% of the total cost of production, therefore, land is not a good measure of farm size distribution, as other production factors have much greater influence on it.

One alternative measure is gross farm income. The 2006 Agricultural Census included in its database information about self-consumption on the farm and the share of production that is sold in the market, with both being used to estimate gross farm income (at market prices), and gross farm income being divided into classes of minimum wage in Brazil (at 2006 prices) . The social class receiving the equivalent of less than one minimum wage contributed less than 2% of the agricultural value of production, and will not be considered in this discussion.

The first class was for farms with more than one and up to two minimum wage equivalents per month. This class accounted for 27% of the farms in the set and was denoted as the poor farms class. The intermediate class represented medium-income farms, those that received from two up to ten minimum wage equivalents per month and represented roughly 50% of the farms analyzed. The third and final class represented the rich farms, those that received more than ten minimum wages per month.

In this normal distribution, family farms belonged to the first two classes. Most of their production was for the domestic market, but they also contributed to exports. The rich farm class produced for both foreign and domestic markets, and the amount for each market depended on relative prices: international compared with domestic prices. Most of the commercial farms belong to the rich class.

An interesting exercise is to explore gross income concentration as opposed to farm size (measured in hectares). We considered two groups of farms, those less than or equal to 100 hectares in size, and those greater than 100 hectares in size, and calculated the Gini coefficient for each group. For medium to small farms (100 hectares), the Gini coefficient was 0.85, while for larger farms, the corresponding result was 0.87. As a Gini coefficient value of 1 expresses a state of maximum inequality (one group in this case would accrue all the income) it can be concluded that the income concentration measured by the Gini coefficient is not related to the agrarian structure (that is, the farm area in hectares) because concentration is high in both groups.

In a recent assessment, it was shown that in dynamic agricultural regions in the Cerrado, both GDP and the Human Development Index were higher than in less dynamic regions . In fact, an incipient agricultural region such as the Brazilian northeast contained most (about 60%) of the poor farms . The remaining 40% of the poor farms were evenly distributed across the other regions (north, southeast, south and center-west) of the country . The intermediate and rich farms were present in all five regions, with a slightly higher concentration of rich farms in the midwestern region. Hence, public policies have been correctly targeted to stimulate income growth in family farms, both for their benefit and for that of the domestic food market.

Regarding the technology issue, some key technologies that will eventually be supported in the near future are: new varieties and cultivars (adapted to non-native ecosystems, with a higher yield in a given environmental set of conditions, resistance and/or tolerance to biotic and abiotic stresses, incorporation of biotechnology and nanotechnology tools); new inputs (machinery and equipment, fertilizers and agrochemicals); and new agricultural practices and innovative production systems (providing greater efficiency in water and nutrient use, and accommodation of multiple crop cycles in a year). Obviously, the research system and the extension service must receive adequate financial support in order to sustain continuous gains in agricultural yields in farms.

Thus a main future challenge for research, given the ample array of stakeholder pressure and funding possibilities, is clearly and objectively identifying the sequence of relevant problems that shall be solved by research in order to increase welfare in society . Additionally, gains in productivity benefit the whole society, but poor families in rural areas and in cities receive the greatest share of these benefits, because the greatest share of the poors income is spent with food acquisition. Thus, reducing the price of food works as income transfer to the poor without the need for reallocation of income within society.

For this reason, agricultural policies need to be designed to support research efforts that stimulate growth in productivity. Given current and future societal demand, this growth in productivity will need to focus on the development and/or adaptation of resource-saving (for example, land, water, and nutrients) technologies that protect the environment and use resources more efficiently.

It is desirable that these novel technologies should also contribute to mitigate carbon emissions under a green growth strategy. Agricultural policies in Brazil already promote the importance of expanding the use of low-carbon agricultural technologies. In the 2011-2012 Agricultural and Livestock Plan of the Ministry of Agriculture, Livestock and Food Supply, the Low Carbon Agriculture (ABC) credit line has R$3.15 billion (approximately USD$1.75 billion) allocated to it, with annual interest rates of 5.5%.

In accordance with the Law on Climate Change that was approved in December 2009, it is estimated that the agricultural sector (through recovery of low-productive pastures, and stimulus to increase adoption of integrated croplivestock systems, BNF usage, and high-quality no-till planting) and the biofuel sector will be able to reduce the greenhouse gas emissions related to the baseline scenario by 226 Mega tonnes of CO2 equivalent by 2020. This implies that the agricultural sector alone may be responsible for 21.5% of the mitigation actions proposed by the Brazilian government. Pasture intensification, by avoiding further deforestation, freeing up large areas of pasture to accommodate crop area expansion, and directly or indirectly reducing greenhouse gas emissions, will play a decisive role in this process .

The development of Brazilian agriculture was greatly boosted by the forced-draft industrialization policy taking place in the country between 1960 and 1985. In this process, a large share of the countrys geographic area, the Cerrado, which was once thought to be of limited value for agricultural production, proved to be a productive region when scientific knowledge and sound policies were used by entrepreneur farmers. The experience of the agricultural transformation in Brazil is proof that it is possible to have an efficient and competitive agriculture in the tropics.

The development of Brazilian agriculture was predominantly based on productivity gains. Again, science played a pivotal role in the development of land-saving technologies. There are clear opportunities to advance in this path of sustainability while at the same time expanding the production of food, biofuel, and fiber. Intensifying pastoral systems will be of central importance in such a policy.

Agricultural technologies in accordance with a green growth strategy, consistent with environmental protection in the long term, using natural resources within their carrying capacity, while providing acceptable living standards and poverty reduction) are already available and are increasingly being adopted by Brazilian farmers. However, the design of innovative financing mechanisms will be essential to foster and speed a large-scale adoption of technology .

Finally, from a global perspective, the increase in agricultural exports in Brazil reflects the important contribution of the country to reduce world hunger and macroeconomic (inflationary) pressures, and to stabilize prices in agricultural markets. This ability to expand its agricultural production in a sustainable, scientific-based path will inevitably strengthen Brazils role in world markets in the near future.

Small Farmers

1. The structure of agricultural production in developing countries has radically changed in the last two decades. Since the late 60s and 70s, the World Bank and its various agricultural research institutes have actively promoted the adoption of industrial (high chemical input) agricultural methods such as the Green Revolution ‘miracle’ seeds, promising landfall yields. These high technology methods were expected to benefit all farmers, including the poor. Since yields would increase, incomes were also expected to increase.
2. However, the heavy dependence on imported inputs could not be sustained economically by developing countries. This was compounded, in the 1970s and 1980s, by the oil crisis and the debt crisis. The economic and financial crisis in developing countries led to the proliferation of loan packages from the international financial institutions. Structural adjustment policies were then introduced as a condition for loans borrowed by countries. Since the 1980s, close to 100 countries have been forced to take on structural adjustment packages. The policies included on the one hand forced liberalization, and on the other, the conversion of domestic agricultural production for exports.
3. Over the last two decades, the experience of small farmers from Central to South America, Africa and Asia have been strikingly similar. Many have been pressured to switch from diverse traditional polycultures to monocultures for overseas markets. For example, the provision of extension services and credit were often conditioned upon farmers accepting the new technologies in export crops that were promoted. Farmers have been likewise forced to switch to export crops when local prices in staples and traditional crops have plummeted as a result of cheap subsidized imports often from the industrialized countries flooding the local markets. For the majority of small farmers, the process has been one of systematic impoverishment. Many have even been squeezed out of farming altogether. Instead of abating food scarcity, which has always been the reasoning for public investment in agricultural technology and hybrid seeds, food surpluses are increasing on the world market, yet ironically, for those most in need, hunger and food insecurity remains more of a problem.
4. The Green Revolution technical fix focused narrowly on increasing yields is clearly not the answer. The Gene Revolution today, is headed towards compounding the already serious problems faced by the rural sectors in developing countries.

5. This paper will explore how the industrialization of agriculture, the increasing concentration in production, the emphasis on exports, and the removal of barriers even for staples have been detrimental for small farmers' livelihoods and also food security in developing countries. The market does not respond to those in need but to those with financial prowess and bargaining power. The paper will also look at alternative food production methods for small farmers in developing countries that can ensure their livelihoods, their food security, as well as the long-term sustainability of food production. The final section will be on recommendations for the WTO's Agreement on Agriculture (AoA).

II. Small Farmers and the Market

6. Why focus on small farmers? In developing countries, agriculture continues to be the main source of employment, livelihood and income for between 50% - 90% of the population. Of this percentage, small farmers make the up the majority, up to 70 – 95% of the farming population. Small farmers are therefore a significant proportion of the population. They have traditionally survived on subsistence production. Many in the last 2 decades have experimented with export crops with occasional initial success but many disastrous failures.
7. The industrialization and export orientation of agriculture has not benefited them. In the globalised market, the small players have been marginalised, as will be illustrated below. Yet economically, they should not be ignored. Policies which have led to their marginalisation has meant the continuation of the vicious cycle of poverty for sectors of society, highly uneven development and hence the inability of many developing countries to attain satisfactory levels of overall development.
8. Analysts Conroy, Murray and Rosset (1996) write about how many developing countries cannot achieve a satisfactory level of development because their small farmers have been sidelined:

> ‘It is our belief, and that of respected economists (Janvry 1981) and Jeffrey Sachs (1987), that the sort of inequity and poverty the peasantry must face actually blocks true development. The rural masses are so poor that they have little purchasing power. They thus do not constitute an important market for domestic industry. This in turn means that domestic markets are too small to stimulate much economic activity, so production is largely directed toward foreign markets and urban elites. As a consequence, the level of demand in the economy is too narrow to sustain broad based, effective development. This creates a high degree of dependence on foreign markets and a lack of structural incentives (nationally, that can bring about) better living standards for the poor. In short, poverty becomes a vicious circle that is itself an obstacle to development.’

9. Prior to Bretton Woods and WTO liberalization, many farmers in developing countries were protected through a combination of policies such as tariffs, quantitative restrictions especially on staples, through subsidies which artificially reduced the costs of inputs, or through support prices which increased the price farmers got for their commodities. These policies had the effect of protecting the livelihoods and employment of those in the rural sector.

III. Are Industrial Agricultural Methods Alleviating Hunger?

10. Industrial agriculture generally means the dependence of food production on high inputs -- chemical fertilizers, pesticides, water, as well as the increasing use of machines. Industrial farming entails extracting maximum output from the land in the shortest possible time. Food production becomes similar to a ‘mining’ operation.
11. A landmark in the spread of industrial agricultural methods was the Green Revolution, which brought the advent of ‘miracle seeds’ in the 1960s and 1970s. It was found that these improved varieties dramatically increased yields as compared to traditional varieties.

12. According to analysts Lappe, Collins and Rosset, the main reason why ‘modern varieties’ produce more than traditional varieties is that they are more responsive to controlled irrigation and petrochemical fertilizers, hence allowing for much more efficient conversion of industrial inputs into food. Other researchers such as Palmer of the UNRISD has termed them ‘high-responses varieties (HRVs), rather than high yielding seeds. In the absence of the fertilizers and irrigation, the new seeds in fact have lower yields than indigenous varieties.
13. The miracle seeds were first cultivated for cereals, such as rice, wheat, maize and cassava, but were broadened to a list of 27 commodities later. By the 1990s, almost 75 per cent of Asian rice was sown with the new varieties. The same was true for almost half of the wheat planted in Africa and more than half of that in Latin America and Asia, and about 70 per cent of the world’s corn as well. It has been estimated that about 40 per cent of all farmers in developing countries were using Green Revolution seeds by the 1990s, with the greatest use found in Asia, followed by Latin America.
14. Did the Green Revolution reduce hunger? Comparing the number of hungry people in the world in 1970 versus 1990 (spanning the two decades of major Green Revolution advances), a first glance seems to indicate significant progress. The total food available per person in the world rose by 11 per cent. The number of chronically undernourished fell from 942 million to 786 million, a 16 per cent drop.
15. However, on closer examination, and if China was eliminated from the analysis, the number of hungry in the world actually increased by more than 11 per cent, from 536 million to 597 million. In South America, where per capita food supplies rose almost 8 per cent, the number of hungry people went up by 19 per cent. In South Asia, there was 9 per cent more food per person by 1990, but there was also 9 per cent more hungry people. It was also not due to increased population that brought about greater hunger. The total food available per person in fact increased. It seems that greater hunger was the failure to address unequal access to food and food-producing resources.
16. Analyst Vandana Shiva terms the effects of the Green Revolution and the industrialization of agriculture as ‘inequality-generating’.

IV. The Social and Ecological Costs of Industrial Agriculture

18. The following sections will explore the social and ecological costs of modern industrial agriculture as experienced by many developing countries. Particular emphasis will be paid to the effects on the rural poor / small farmers, and food security.

A. The Social Costs of Industrial Agriculture

19. How does agricultural industrialization and production for the export market lead to the uprooting and destruction of small farmers while benefiting the large farms? According to Shiva, agricultural industrialization and exports increases single commodity harvests. With all farmers growing the same commodity over large areas, the prices farmers receive from their crops come down, while the costs of inputs which are imported have been on an upward spiral. As a result, farmers’ profit margins get drastically narrowed. As costs of production increase, farmers experience a cost-price squeeze. In this process, only the larger farms can survive.

1. The market is such that the costs for small farmers to use the high input system are larger than for big farmers. Poor farmers cannot afford to buy fertilizer and inputs in volume. Big growers get discounts for large purchases. Poor farmers cannot hold out for the best price for their crops, while larger farmers whose circumstances are less desperate can. Big farmers can afford to pay for irrigation services, which may not be within reach of small farmers.

B. Industrial Agriculture’s Need for More Chemical Inputs for Decreasing Outputs

22. Yield increases from high yielding Green Revolution technologies have been decelerating, and in some cases stagnating and even contracting. The highest yields have been obtained by using ever larger inputs of fertilizer and irrigation water, which in many places have passed the point of diminishing returns. Greater use of these inputs is becoming less productive.

1. In comparison to traditional varieties, outputs are small. Traditional rice farming in Asia produced 10 times more energy in food than was expended to grow it. Today's Green Revolution rice production cuts the net output in half. According to Cambridge University Geographer, Bayliss-Smith, the gains drop to zero in a fully industrialized system such as that of the US.
2. In India, adoption of the new Green Revolution seeds led to a six-fold increase in fertilizer use per acre. Farmers used an average of 12.7 kg/ha of fertilizer in 1970. By 1995, usage had gone up to 76.6 kg/ha. While food grain production increased 84 per cent from 82 million tones in 1961 to 185 million tones in 1997, consumption of chemical fertilizers rose from 292 thousand tones in 1961 to 16,422 thousand tones in 1996-97, a 15,000 per cent increase.
3. Similarly, in the Philippines, rice production increased in the late 1970s, and early 1980s as a result of the Green Revolution, but has since been on the decline. Analysts attribute it to these 'high yielding varieties'.
4. Why is this happening? Experts are concluding that clearly, chemical fertilizers are destroying the quality of the soil. Yields are falling because chemical fertilizers are not a sustainable source of soil fertility. In the long run, these methods encourage desertification, soil erosion, pesticide contamination and the depletion of groundwater. Yet these ecological problems are ignored because of the difficulty in quantifying and assigning monetary values to ecological degradation. These remain hidden costs behind the yields obtained in conventional farming.

C. Industrial Agriculture's Inefficient Resource Use

27. One of the myths about industrial agriculture is that it is a land-saving system. In fact, monocultures and the separation of crops from livestock necessitate much higher amounts of land than traditional polycultures, and systems integrating crops and livestock.

1. Since monocultures eliminate diversity and the multiple uses of land, and instead provide a single output, additional acres are required to produce the output which would otherwise have been produced on the same piece of land.
2. Shiva explains it as follows: If traditional varieties produce 1000 kg/acre grain and 1000kg/acre fodder, then industrial varieties produce 1200 kg/acre of grain and 0 kg of fodder. Thus another acre has to be used for fodder

production. The two acres, without chemical inputs and new seeds, could have produced 2000 kg grain plus 2000 kg of fodder on 2 acres.

3. Likewise, crop production strategies which ignore livestock as an important source of soil fertility leads to the intensification of agriculture through the use of non-sustainable chemical inputs for fertilizers.
4. In addition, industrial livestock farming in fact consumes three times more acres of land than ecologically rearing livestock. Analysts have calculated that Europe in fact uses seven times the area of Europe in Third World countries for cattle feed production. For fodder alone (including that used to produce food products for export) the Netherlands appropriates 100,000 to 140,000 square kilometers of arable land. This is often referred to as ‘shadow acres’ and much of it comes from developing countries. This is 5-7 times the area of agricultural land in that entire country.

32. It has been concluded that the combination of industrial plant breeding and industrial animal breeding increases the pressure on land-use by a factor of 400% while separately increasing output of grain and milk by only a factor of 20%.

1. Shiva concludes that one acre of a farm that only uses inputs derived from the farm itself with integrated livestock and crop production can support a family and two farm animals. If both crop production and livestock are made to rely on intensive inputs, the same family and two animals require additional shadow acres of land to produce the inputs and absorb the pollution.
2. The other resource which is overused by industrial agricultural methods is water. As mentioned earlier, high-response seeds grow well only when water is plentiful. The water tables, however, are falling in key food-producing countries. 480 million of the world’s 6 billion people are fed with grain produced by overpumping aquifers. This is already creating serious water shortages in various countries today. Regions suffering from aquifer depletion include central and northern China, northwest and southern India, parts of Pakistan, much of western United States, North Africa, the Middle East and Arabian Peninsula. Besides constraining future food supply, groundwater overpumping is widening the income gap between the rich and poor. The poor cannot afford to deepen their wells or buy stronger pumps. As the shallower wells dry up, some of the small-scale, poorer farmers end up renting their land to the larger well owners and become labourers on these larger farms. Agronomic systems of agricultural production, for example, intercropping to maximize use of soil moisture, as well as better

matching crops to climate conditions can reduce the pressure on water supply, and increase the opportunities for small farmers to maintain their livelihoods.

3. The point made here is that extra resources used by the industrial systems, such as Green Revolution techniques, could have gone to feed people. These systems are resource wasteful and rely on intensive external inputs, including water and land. The emerging Gene Revolution (which is similarly input-intensive) promises to be as resource wasteful. These systems take away the entitlements from those most in need, and add to food insecurity and poverty in developing countries.

D. Monocultures, Pesticide Poisoning and Overuse

36. Another significant issue that must be addressed as a result of industrialized food production systems is the increasing dependence on pesticides. Monocultures erode diversity. It is diversity that increases resistance to pests. In a holistic system, a problem in a part of the system can be absorbed or counter-balanced by the entire system. This is why the polycultural system is widely recognized as more stable. This is not the case with monocultures. Without the advantages of a balanced eco-system, pest infestations are common, so that the entire crop can be easily destroyed.

1. Chemical pesticides are in fact creating more pests than controlling pests. By contributing to the emergence of resistance in pests and by destroying natural enemies and predators, pesticides increase pest problems. Globally, 450 species of insects and mites, 100 species of plant pathogens, 48 species of weeds have become resistant to one or more pesticide products. In California, of 25 insect pests, 72 per cent are resistant to one or more pesticides and 96 per cent are pesticide created or aggravated.

38. The strengthening and growing resistance of pests is hardly surprising given that 4.7 billion pounds of pesticides are used annually throughout the world. World pesticide use has increased 26 fold in the last 50 years. In 1996, total pesticide sales topped $33 billion. The value of world exports of pesticides increased more than eight times in less than four decades, from $1.3 billion in 1961 to $11 billion in 1997. Most exports originate from industrial countries.

1. The other facet of the pesticide problem are the costs to human health. Estimates of pesticide poisonings in the third world are as high as 25 million people yearly. Many cases go unreported, partly because growers' actively prevent reporting.
2. The most harmful chemicals end up in developing countries. Many industrialized countries continue to export chemicals that are deemed too deadly for domestic use. Despite the awareness of bioaccumulating chemicals (ie, each link or species in the food chain takes up the previous link's exposure, adding it to their own and magnifying the effects), this trend is getting worse. Between 1992 and 1996, US chemical companies increased exports of domestically prohibited pesticides by 18 per cent. The rate of exports of pesticides that have never been registered jumped 40 per cent during this time. More than 14 per cent of all US pesticide exports are in some way restricted from use within the country itself.
3. Beyond causing cancer, new evidence suggests that pesticides may have many other dangerous effects. For example, many pesticides fall into a category of chemicals called 'endocrine disrupters', some of which directly affect the reproductive system.
4. Much of the problem with the use of pesticides has to do with meeting the cosmetic standards of consumers in the export markets, particularly the industrialized countries. Lappe, Collins and Rosset estimate that in the US, from 60-80 per cent of the pesticides applied to oranges and 40-60 per cent of that applied to tomatoes are used only to improve appearance. Less than 0.1 per cent of the pesticides applied to crops actually reach target pests. The rest moves into ecosystems, contaminating the land, water and air.
5. Unfortunately, it is again the poor farmers who are much less able to weather the increasing costs. As pests become more resistant to chemicals, larger amounts of pesticides are required – what is referred to as the pesticide treadmill. In the research in Guatemala mentioned above, pesticide costs for melons ranged from $735 to $2,206 per hectare. These high costs have left small-scale producers counting on unusually high international market prices, or left in a state of deep debt.
6. There are other organic alternatives to chemical pesticides, such as the various integrated pest management methods. These include crop rotation and mixtures to increase diversity, introduction of natural enemies of pests, and the application of natural organic pesticides, for example, some African farmers use cow urine on certain crops.

V. How Much of the Consumer Dollar Does the Farmer Get?

45. The industrial agricultural system has been evaluated on its social and ecological costs above. However, another aspect to it is that with its export orientation and accompanying trade liberalization policies, the commodity chain has broadened, so that farmers are small players amongst the big transnational seed, chemical, export, processing, shipping and retailing companies. This has drastically cut down the returns accruing to farmers, as well as the control farmers have over the prices they get.

1. The entire commodity chain can be broken into three parts, prefarmgate, inside-farmgate and postfarmgate. Prefarmgate refers to the manufacture, procurement and delivery of all goods and services the farmer needs to produce the crop. Inside farmgate includes all the activities carried out by the farmer. Postfarmgate operations include all actions between the farm and the final consumer.
2. While the farmgate prices paid to farmers have been on the decline in the recent years, there has been no or little decline in consumer prices. Where is the consumer dollar going and who receives the bulk of it?
3. Conroy, Murray and Rosset observe that in industrial agricultural systems when commodities are exported, as opposed to more traditional systems, the vast bulk of the value-added, and consequently, the lion’s share of the profits tend to lie at the extreme: the pre and post farmgate segments. In fact, the overwhelming bulk of value is added postfarmgate (eg. up to 89 per cent for melons from El Salvador exported to the US). For each pound of melon produced by a small El Salvadoran farmer and retailed in the US for 65 cents, the farmer reaps at best 0.6 per cent of that revenue. More than 90 per cent of the revenue accrues outside the country -- 75 per cent goes to US shipping, wholesaling, advertising and retailing.
4. The experience of small farmers in the North is similar, although they are in a slightly better situation. According to the Canadian National Farmers Union, farmers in 1975 used to obtain 13 per cent of the retail value of bread. Today, this is a mere 4 per cent. If these amounts take into consideration assets and debts of farmers, then farmers earn 0.7 per cent

equity on average between 1994-98 in the commodity chain. In 1998, this percentage was only 0.3 per cent on average for all farmers. Indeed, the Union has calculated that while farmers growing grains – wheat, oats, corn – earn tiny or negative returns, the companies that make breakfast cereals reap huge profits. In 1998, Kellogg's, Quaker Oats, and General Mills enjoyed return on equity rates of 56 per cent, 165 per cent and 222 per cent respectively. That is, these cereal companies were 186 to 740 times more profitable than the farmers.

5. Clearly, small farmers are being squeezed hard while the exporters and transnational corporations carrying out the processing and retailing are making a disproportionate amount of profits in the commodity chain.
6. It is therefore small wonder that for developing countries, food production for exports has not brought in the revenues expected, especially as the pre and post farmgate operations are dominated by corporations from the industrial countries. In addition, developing countries are constrained from entering into higher value processing of their commodities (post farmgate processing) due to the tariff structure and tariff escalations in developed countries.
7. In contrast, production of food products for the local market immediately cuts down the number of intermediaries, provides the farmer opportunities to have more direct access to the consumer / market, and therefore much greater control over the pricing and their level of profitability.

VI. Equality-generating, Affordable and Agroecological Food Production Systems

53. If the small farmers in developing countries are to survive -- and they must if broad-based development is to take place in developing countries -- we need more equality-generating forms of food production, which can continue to provide small farmers with a viable source of livelihood, and access to their daily food needs.

1. Small farmers are the losers when food production systems erode the environment and soils, while transnational operators move to greener pastures. We need more environmentally sustainable forms of farming that nurture rather than exploit the resources needed for long-term food production.
2. We also need production systems which rely more on locally available inputs. Farmers cannot benefit from technologies and inputs which are not available, affordable, or appropriate to their conditions. In particular, purchased inputs such as pesticides, fertilizers and even 'high technology' seeds, present special problems and risks for less-secure farmers, especially when they need to borrow in order to make their purchases.
3. Rather than chemical intensification, as the industrial methods promote, Shiva has suggested a shift towards other forms of intensification that can address the ecological needs and the affordability criteria for small farmers:

> i) the intensification of biodiversity rather than use of external inputs
>
> ii) the intensification of crop-livestock integration and cooperation rather than that of competition between crops, livestock and humans
>
> iii) the intensification of internal inputs for both crops and livestock, such as local labour and knowledge.

57. To move beyond industrial methods of agriculture involves evaluating productivity on an entire farm system, rather than in terms of specific commodities. This would include the farm's year to year stability, its sustainability and the productivity of its diverse elements, instead of thinking in terms of this year's output of the top cash crop.

1. Agroecological approaches to agriculture include methods such as intercopping, crop rotations, agroforestry systems and, as referred to above, the integration of plant and animal production – all time-honoured practices of farmers.
2. With intercropping, several crops grow simultaneously in the same field. Rotating cereals with legumes (with fix nitrogen in the soil for use by other plants) and interplanting low-growing legumes with a cereal helps to maintain soil fertility without costly purchased fertilizers. Intercropping also

works better because different plants have different needs and different timings of those needs. It therefore takes better advantage of available light, water and nutrients so total growth takes place. Instead of depleting the soil, as does monocropping of row crops (with the soil between the rows exposed to rain and wind erosion), intercropping increases the organic matter content of soils. The land taken to cultivate the crops together is therefore also less than if the crops were cultivated separately. Traditional methods have been known to accommodate as many as twenty-two crops in the same field.

3. Integrating crops and animals on the same farm allows the return of organic matter to the fields. Using ducks or geese in rice farming, for example, can reduce weeds without herbicides.
4. These alternative methods are sometimes referred to as low-input technologies. However, as was mentioned above, this designation refers to the external imported inputs required. The amount of labour, skills and management required as inputs to make the land productive is in fact quite substantial.

VII. The Benefits of Alternative Food Production Systems

62. The benefits of these alternatives can be summed as follows:

A. Yield Increases

63. Some may wonder whether the small farmers will be able to produce sufficient food for themselves with agroecology. Projects in alternative production methods in fact commonly result in increases in production of 50 – 100 per cent. In some of these systems, yields of crops that the poor rely on more – rice, beans, maize, cassava, potatoes, barley – have been increased by several-fold, relying on labour and traditional know-how more so than on expensive purchased inputs. For example, some projects emphasizing green manures and other organic management techniques can

increase maize yields from 1-1.5 tones per hectare (a typical highland peasant yield) to 3 – 4 tones per hectare.

B. Yield Stability, Resistance to Pests and other Ecological Benefits

64. Not only are yields increased, but crops in fact display more stable levels of total production per unit area than the industrial systems. For example, the yield variability of cereal / legume polycultures is much lower than for monocultures of the components.
65. Furthermore, agroecological systems protect and conserve the soils as well as ensure better water management and harvesting. These methods also enhance biodiversity. Genetic diversity in turn increases resistance to pests and diseases.
66. These benefits ensure the long-term sustainability of food production. Because they are not easily quantifiable, they have been left out of conventional agriculture's much more linear, single-dimensional method of calculating costs, outputs and profits.

C. Provides a Sustainable Livelihood, Poverty Alleviation and Rural Development

67. Perhaps the most important dimension of agroecological food production is that they can provide a decent livelihood for small farmers, with fair returns to their labour - *if* there is a supportive larger policy environment. These systems have the potential to offer economically favourable rates of return since the costs of inputs are not exorbitant.
68. The potential benefits to small farmers include increases in food supply, increases in incomes, reduction of poverty, reduction of malnutrition and general improvement to small farmers' overall livelihoods.
69. This therefore would go a long way towards poverty alleviation, as well as bringing about overall rural development.

VIII. Developing Countries CAN Produce Enough Food With These Alternative Methods

70. The big question that many skeptics would ask is: why then is there so much food scarcity in developing countries? If industrial agriculture and cheap subsidized imports from the North eliminated, can developing countries produce enough food for themselves?

1. Analysts Lappe, Collins and Rosset explore this question with regard to Africa. Africa is home to 213 million chronically malnourished people (25 per cent of the total in developing countries). By 1995, over one-third of the continent's grain consumption apparently depended on imports. However, according to researchers, Africa has enormous, still unexploited potential to grow food. In countries notorious for famines, the area of unused good-quality farmland is many times greater than the area actually farmed. A central reason for Africa's lack of food production is due to the colonial land grab that has continued into the modern era. It has displaced peoples and production of foodstuffs from good lands toward marginal ones. The good land is mostly dedicated to the production of cash crops for export or is even unused by its owners. Also, public resources, including research and agricultural credit, have been channeled to export crops to the virtual exclusion of peasant-produced food crops. Since the 1980s, the pressure to export to pay interest on foreign debt has reinforced this imbalance.
2. The other factor which has greatly impoverished African peasants is the subsidized food surpluses from the developed countries which are dumped on Africa. This often takes away the entire local market for the local producers, who end up in debt, landless or even bankrupt.
3. Today, agribusiness companies are promoting the 'life sciences' and its genetically modified seeds and production methods as the new revolution that will answer the question of hunger in the world. There are promises of yield increases, pest resistance, and even foods that are more nutritious (e.g. Vitamin A rice). Unfortunately, like the last revolution, the hunger problem has been premised wrongly, with the assumption that there will not be enough food to feed the world, rather than the more pertinent question about food distribution and access.
4. Genetically modified (GM) seeds and production methods will bring about outcomes for small farmers which are similar to the Green Revolution experiences. GM crops are also high chemical input crops. The socially

inequitable outcomes will be the same and may be even worse, since the technology is patented by transnational corporations. Small farmers will be in the same position in the commodity chain. They will be at the mercy of intermediaries, contractors and exporters and will have to bear the brunt of all weather and crop risks. They will receive similarly meager returns, if any, in contrast to the players in the pre and post farmgate operations -- i.e. the transnational food, transport and retail corporations.

5. In addition, the ecological risks are likely to be as damaging. All the evidence to date points to as much or increased pesticide use. Weeds and pests are also likely to gain genetic resistance to pesticides. GM crops will also be planted as monocultures, hence the ecological problems associated with the hazards for biodiversity will be present. The damage may be even more pronounced given the as yet unknown metabolic effects of genetically modified crops and their spread to their wild relatives, not to mention the still unknown health effects it could have on consumers.
6. Rosset, Collins and Lappe conclude that

> ‘Introducing any new agricultural technology into a social system stacked in favour of the rich and against the poor -- without addressing the social questions of access to the technology’s benefits -- will over time lead to an even greater concentration of the rewards from agriculture’.

77. In a similar vein, experts Altieri and von der Weid observe that ‘If the root causes hunger, poverty … are not addressed, hunger will persist no matter what agricultural technologies are used. Most modern agricultural technologies have the potential to deal with the issue of quality and quantity of food, but does not address the distributive and access aspects of food which are at the heart of the hunger problem.’

78. They conclude that to insist on only technological solutions to hunger ignores the tremendous complexity of the problem of food scarcity.
79. Indeed, the UN has projected recently that there will be ‘drastic deceleration’ in world demographic growth. The world population is expected to be 8 billion in 2030. The growth rate of the world population, which had peaked in the second half of the 1960s at 2.1 per cent per annum had fallen to 1.3 per cent by the late 1990s will fall to a mere 0.3 per cent by 2050. A very recent FAO study has concluded -- without taking into

consideration any production differences that may result from genetically modified crops -- that ‘for the world as a whole there is enough, or more than enough, food production potential to meet the growth of effective demand, i.e. the demand for food of those who can afford to pay farmers to produce it’. That is, the residual hunger problems will be largely poverty, rather than production related.

80. According to Amartya Sen, famines have occurred not because of shortage of food, but because people’s claim to food is disrupted. When people are denied the resources to grow or retain enough of their own harvests to meet family needs, and when only buying power / money, gives people claim to additional food, many will go hungry, and even starve if their income falls or food prices dramatically rise.
81. People’s incomes are very vulnerable to fluctuations. They may fall because they lose their means to produce. Poor people might have to sell their land or animals because of a death in the family, or mounting debts might mean that they lose their land after a single bad harvest. Often the price of what the poor produce suddenly drops, leaving them unable to buy enough food.
82. In short, if the people’s claim to food is only through the market, yet the prices they get remain volatile as a result of not having control over prices, then people will die in famines, no matter how much food is produced. Global food security is therefore not a substitute for domestic or local food security.
83. The main reason why people go hungry is not due to a shortage of food, but remains an issue of access and whether they have the entitlements needed to produce their own food for their families’ consumption.
84. Alternative egroecological methods of producing food for family and local consumption is, in contrast to industrial high-input systems, an option that can provide the rural poor with stable food supplies, adequate access to food, livelihood security and ecological sustainability for continued long-term food production.

IX. Policy Recommendations

85. It is critical for small farmers in developing countries to have adequate protection from drastic liberalization measures since the market does not work in their favour, but in favour of the big players.

1. Trade policies must therefore provide small farmers and the rural poor in developing countries the protection needed to ensure the continued viability of their livelihoods. They also need protection against dumping and unreasonable competition from subsidized producers abroad. Providing greater security for the rural masses will bring about more even and equitable development for countries as a whole.
2. Furthermore, for reasons of food security, national, political and economic security, as well as due to the special place of agriculture in developing countries' economies (see paper on 'Special and Differential Treatment and a Development Box', G/AG/NG/W/13, June 2000), developing countries also need policy flexibility to ensure that existing production of staples and food crops for domestic consumption are not threatened, and, if insufficient, can be increased.
3. To these ends, we recommend the following:

A. Demolish WTO's Single Undertaking Structure:

89. The WTO's present single undertaking structure should be modified into a more flexible and development friendly, plurilateral, a la carte structure. Developing country members should be given the flexibility to sign-on to only those agreements which their economies and industries are ready for and which they can benefit from. This should be considered a central component of effective and real Special and Differential Treatment.

1. (This suggestion should not be confused with the present EU suggestion to include new issues as plurilateral agreements. There should not be inclusion of further new issues not only because the system is overloaded, but because they are go beyond the trade arena and infringe on countries' domestic sovereignty. Developing countries today need more policy space to chart their development direction, not less).
2. In terms of agriculture, such a plurilateral structure would mean that those developing countries whose agricultural sectors are not ripe for competition, and whose small farmers and food security will be severely affected, will be able to opt out of the agreement until such time their farmers and economies

are ready. This is particularly important given the unfair competition and dumping which characterizes a large part of developing countries' trade with the industrial countries. This is not to recommend countries to close up, but to acknowledge that big bang liberalization has caused much damage for the most vulnerable sectors, and that developing countries, with a host of different development needs, should have the flexibility to carefully time and structure their own integration with the world economy.

B. Create a Development Box for Developing Countries

92. A Development Box should be added to the existing Agreement on Agriculture (AoA) with the following components for *developing* countries:

a. Members signing on to the Agreement should be able to use a positive list approach to declare which agricultural products or sectors they would like disciplined under the provisions of the Agreement. That is, only the products which are declared by a country are subject to AoA commitments.

b. The reduction of tariffs has had detrimental impact on many developing countries. They must be allowed to re-evaluate tariff levels, and to revise them as and when the need arises in order to increase their domestic food production capacity, as well as protect livelihoods, employment and also local biodiversity. It is important that a country is able to act immediately and autonomously.

c. An appropriate safeguard clause that is only for developing countries in order to protect products that are important for domestic consumption and to protect the livelihoods of small farmers.

d. The minimum access import opportunity developing countries now currently have to provide should be abolished.

e. Flexibility in the area of domestic supports for food security, protection of rural livelihoods and for maintaining and increasing domestic food production for domestic consumption.

C. Market Access

a. Tariff peaks in developed countries should be reduced. High OECD tariff peaks exceed 100 per cent. According to UNCTAD / WTO, this level of tariff peaks is rare in developing countries. A formula, such as the Swiss formula could be used to bring down the extremely high tariffs of developed countries by larger amounts to more reasonable levels.
b. Eliminate tariff escalation of developed countries. This is extremely important if developing countries are to diversify their economies. A harmonisation formula should be designed to eliminate tariff escalation, including the provision of the full liberalisation for tropical products in processed forms by developed countries.

D. Domestic Supports

93. Collapse all domestic support categories into one ‘General Subsidies’ box. This means the elimination of the Green Box, the Blue Box and the Amber Box. One category of subsidies will bring rationality and structure to the Agreement. It will also ease the unnecessary administrative burden on under-resourced developing country delegations.

1. A common level of supports should be allowed eg.10 percent of production for all countries. This level of subsidies should be non-actionable. Subsidies of 5 per cent above this level will be ‘actionable’ for developed countries. Subsidies beyond this level are not permissible. Developing countries will be allowed additional flexibility under the ‘Development’ box to protect food security and to increase domestic production for domestic consumption.
2. Developed countries wishing to provide subsidies over and above this 10 per cent value must be prohibited from exporting these products. Even if these programmes are classified as non-trade distorting, they do invariably increase production levels.

E. Export Subsidies

96. All forms of export subsidies – direct and indirect – must be eliminated immediately. This must also include export credits and other forms of export promotion programmes.

F. Market Structures

97. The consolidation by transnational corporations in the commodity food chain, especially at the pre and post farmgate operations, is anti-competitive and highly undesirable. Size no longer brings efficiency if there are only a handful of players. The coming negotiations must put in place appropriate policies to stop the abuse of market structures by the big companies. These regulations must eliminate the manipulation of prices and increase transparency in market conduct. They should also provide developing countries with an easily accessible mechanism to protect themselves against the abuse of monopoly power and to seek compensation.

G. State Trading Enterprises (STEs)

98. State Trading Enterprises have been criticized by some to distort markets and prices, especially in the case of single desk importers or exporters because they are seen to have control over their markets, are less transparent in pricing, and obtain special privileges bestowed by governments. However, it has been pointed out that these criticisms in fact apply equally or even to a greater extent to the transnational agri-businesses. Many multinationals set prices and operate in a non-transparent fashion. They control not only the domestic but also the international markets as a result of consolidation and mergers, as well as because they have access to huge supplies in many exporting countries.

1. Today, STEs in developing countries continue to play an important development role. In their import, export, and other operations, they ensure stable food supply and access to food, stabilising prices and stimulating production.
2. The removal of STEs will not bring about competition in international markets but we might be eliminating one of the few forms of marketing that is able to withstand the pressure of the currently dominant market players. Instead of a healthy number of private companies emerging to take the place

of the STEs in developing countries, it is more likely that the multinational agri-businesses will expand their operations to absorb the newly created market.

3. Article XVII of the GATT already sets out the parameters by which STEs are to operate in a manner consistent with GATT principles. For developing countries, due to development and food security reasons, Special and Differential Treatment should be applied so that there are no disciplines on STEs beyond those already set out in Article XVII of the GATT. Disciplines on market structure must instead be applied to multinational agri-businesses.

Case Study: Experience of Central America's Peasants in the Conversion from Tradition Agriculture to Non-traditional Agricultural Exports in the 1980s and 1990s.

As a result of Central America's debt crisis in the 1980s and with all countries in the region having an average debt of 51% in proportion to export earnings (ie 51 cents of every export dollar was used for debt repayment), a cornerstone of US economic development policy for that region in the late 1980s and 1990s was the promotion of non-traditional agricultural exports (NTAEs) using high input intensive agricultural methods. This policy was implemented by the US Agency for International Development (USAID) which encouraged exports from the region to markets worldwide, but especially to the US. These NTAEs included melons, strawberries, broccoli, cauliflower, snow peas, squash and other products often shipped fresh directly to supermarkets in the US. The policy was implemented also during the time where many countries were undergoing structural adjustments.

Many small farmers had little choice but to convert to the new crops. Even if they did not wish to do so, their livelihoods were already compromised because 'the viability of traditional corn and bean cultivation had been undercut by trade policies, leaving the rural poor without the peasant safety net of basic grain production for the domestic market and their own consumption'. In this environment, only the big farms producing traditional crops were able to survive the competitive prices.

The export drive in new crops led to some impressive increases in production and exports in some countries. However, for most of the region's poor rural majority, the policy failed to provide any improvement in their dismal living conditions. Instead, researchers Conroy, Murray and Rosset found that conversion to NTAEs 'have tended to undermine small farmers' economic position, drawing them into increased debt and sometimes leading to significant land concentration.'

Some of the commonalities of this 'inequity-cultivating' process included the following:

1) Fluctuation in Prices and Services Offered

Early adopters of new non-traditional crops and technology promoted by foreign agencies (in this case through USAID) would be provided high levels of support – credit, a full-time extensionist, certified disease-free seed, and a purchase contract with an export company. The first year of conversion would be an outstanding success. However, in the second year, seeds and marketing contracts were no longer provided. Yet more local farmers would plant the new crop, based on the experience of their colleagues the year before. The prices would drop in the US in response to new competition from other countries with lower production costs. Farmers often also suffered heavy disease losses due to the poor quality seeds used. Furthermore, some would not be able to find a buyer for their meager production. About 50% would default on their credit. In the third year, this percentage may reach 100%. Subsequently, the market would show a bias against the small producers. Packers and exporters tended to offer contracts to a few large producers whom they felt had better quality control, then to pay the costs of contracting with dozens of small farmers.

2. Rising Rents and Land Values

Many peasants are not legal owners of the land they farm. They are often renters, sharecroppers, or simply squatters. When a new and potentially high-return alternative is introduced into a locality, the opportunity costs associated with traditional peasant land use rises. Landlords earn more by renting their land to those who grow high-value crops. Thus, land values rise while sharecropping opportunities become scarce. If rising land values are accompanied by declining profitability of traditional activities, even landowning peasants may be displaced as it becomes no longer possible to live off traditional production. The situation is aggravated if the start-up capital needed for export production is beyond their means. Peasants may have no alternative but to sell their lands and join the ranks of the landless labourers or migrate to the cities.

3) Capital and Credit: Barriers to Entry

The start up costs for NTAEs were much higher than for traditional crops. In one country, the initial cost barrier for small poor farmers in snow pea production was nearly 15 times the cost of planting basic grains. The poorest farmers would therefore require credit. However, this would be difficult for them to attain as there were strict criteria attached (eg the need for the property title as collateral, official letter stating that one does not have outstanding debts etc), and interests rates charged to them were invariably higher.

4) The Market: A Question of Bargaining Position

It was found that the market place presented not only price fluctuation risks. Farm size was a significant determinant of price. The smaller the farmer's scale of production, the weaker was his or her bargaining power, and the greater the vulnerability to exploitation by intermediaries. Every additional hectare that a farmer planted to melons, for example, translated into payment that was 1-6 per cent higher for the overall produce.

The researchers conclude that nontraditionals offer the worst possible marketing scenario for the small farmer. They are perishable crops that are not usually consumed locally. Should the contract with the importer not materialize, the crops would not fetch a good price locally. In contrast, a farmer who produces a crop for the local market is more likely to have more control over the market. He or she may be at the mercy of middlemen, yet these intermediaries are local people, so that face-to-face complaint and conflict resolution would at least be possible.

5) Knowledge and Technology

Non-traditional crops often require considerable technological sophistication relative to traditional crops, as they are new to the region, or require special care at harvest because of perishability or the need to meet demanding cosmetic standards. The risk of crop failure due to insect pests, disease or inadequate agronomic practices is much higher than in traditional crops. Access to technology, however, is biased against the small-scale producers. Large farms can afford to hire the foreign expertise and buy the equipment needed, whereas small farmers usually rely on extension services which may or may not be provided.

Quality control is also a new problem for small farmers not accustomed to the exigencies of foreign markets. It favours those producers who are able to hire foreign consultants. Peasants may have grown a certain product all their lives. However, the family and local markets had very different standards for appearance, insect presence and damage. In extreme cases, export to foreign markets may be closed to small farmers who do not have the technical knowledge or money to meet the appearance and quality standards required.

6) Need for High Inputs

Many studies have found that new high yielding varieties such as those of the Green Revolution responded to costly inputs. In the absence of such inputs, their yields were actually inferior to traditional varieties. Those farmers who adopted these varieties and who could afford more inputs benefited disproportionately. Those who could not suffered, often eventually losing their land.

The researchers concluded that together with the cutbacks accompanying structural adjustment, combined with dumped US food aid which undermined the historical basis for the survival of the peasant sector, these factors led to ‘unprecedented rural strife’ and an ‘explosive social situation.’

Case Study: Pesticide Problems in Guatemala’s Nontraditional Sector

Research in the Guatemalan highlands where nontraditional crops have been cultivated showed that as farmers were increasing pesticide use, pests were becoming ‘stronger’. Comparison of crops organically grown and those under chemical intensive methods showed that pests were commonly absent in vegetables such as organically grown snow peas, while chemical intensive plots showed relatively high levels of these pests.

When comparing damage due to plant disease of both groups, it was found that damage was considerably lower in organically grown broccoli and snow peas than in fields where they were grown chemically with herbicides, pesticides and fertilizers. Indeed, for snow peas, the damage was 10-times greater for chemically treated plots.

Similarly, in terms of soil quality and soil erosion (the most powerful indicators of ecological well-being), it was found that these were much better for traditional crops (corn and beans) than the nontraditionals. For example, the research found far fewer earthworms (their quantity is an indicator of soil quality) in broccoli fields than in corn, and no earthworms in snow pea fields (those with the heaviest uses of pesticides). The researchers have concluded that ‘heavy and inappropriate uses of chemicals worsen the conditions they were designed to remedy, creating an ecological imbalance for continued production of the same crop.’

Here again, the problems of heavy pesticide use have not affected all players alike. When the ecological problems have reached crisis-generating levels, such as the collapsing of the entire sector due to pesticide residues and pesticide-resistant pests, transnational operators and exporters are quick to close down their operations overnight and move to another locality or region to set up their export operations free of the ecological problems they have created. In contrast, the thousands of farming families left behind have to deal with an ecological crisis on their hands.

Turkish Agricultural Exports

During the past decade, Turkey has emerged as a major exporter of agricultural products, both to the Middle East and other markets. Exports have tripled during this period, and were valued at more than $16 billion in 2013. Out of the top 20 agricultural exporters, only India, China and Ukraine have higher export growth rates than Turkey during the past five years. This growth has continued into 2014, and exports during the first three-quarters of the year are up another five percent.

While trade-distorting agricultural support policies are trending downwards amongst OECD countries, Turkey's support has remained high according to the OECD. Wheat is a major beneficiary of Turkish agricultural support and benefits from minimum purchase prices, input subsidies (diesel, fertilizer and certified seeds), and deficiency (premium) payments. Wheat-specific payments increased significantly from 1996 through 2013. However, as a percentage of the value of production support varied significantly by year due to fluctuations in market prices ranging from 6-52 percent. Since 2004, the minimum purchase price, supported by high tariffs, has increased by more than 40 percent. Further, Turkish processed wheat products (flour and pasta) benefit from export subsidies.

In addition, a number of Turkish agricultural exports benefit from an Inward Processing Scheme (IPS). The IPS has made it possible for Turkish wheat flour, for example, to better compete internationally despite high, protected domestic prices. Due in part to large inflows of Turkish wheat flour, Indonesia has put in place a quota on wheat flour imports, and in November the Philippines put in place anti-dumping duties of up to 16 percent against Turkish wheat flour.

Although the EU-28 remains Turkey's largest export market, nearly all of Turkey's growth in trade has been to developing countries, especially those in the Middle East. In 2013, nearly a quarter of Turkey's agricultural exports went to Iraq. Exports there more than doubled in just three years – from $1.5 billion in 2010 to $3.5 billion in 2013 – led by vegetable oil, flour, poultry and chicken eggs. The turmoil in Syria has also increased import demand there, and Turkish agricultural exports to Syria quadrupled in 2013, and are up another 50 percent in the first half of 2014.

Two other regions that have been increasing markets for Turkish products are the Former Soviet Union and Africa. Turkish exports to Russia, in particular, have been strengthening and could increase even more this year in light of Russia's year-long ban on a wide range of agricultural products from the EU, United States, Canada, Australia, and Norway. Turkish exports to Sub-Saharan Africa have also skyrocketed.

While Turkey has traditionally been a significant supplier of fruit and vegetables, in recent years exports have diversified to include a wide range of products. Some key products which have seen strong growth include:

Sunflower Oil: Turkey is the world’s largest exporter of refined sunflower oil. The majority of these exports are first imported into Turkey as crude oil from Russia and Ukraine, and then refined inside and re-exported, mostly to Iraq and Syria. Turkey’s tariffs on crude oil are considerably lower than the current 50-percent tariff on refined oil, which helps encourage further processing inside Turkey.

Tree Nuts: Turkey dominates world hazelnut trade and accounts for nearly 80 percent of global hazelnut exports. Nearly three-quarters of Turkish exports go to the European Union.

Raisins: Turkey remains the world’s largest exporter of raisins (followed by the United States), accounting for nearly one-third of total global trade. The lion’s share of these exports are to the EU-28.

Poultry: Turkish poultry exports have also been expanding in recent years. In fact, Turkey is expected to be the world’s sixth-largest exporter in 2014. Almost all of these exports are shipped to other Middle East markets, especially Iraq. Turkey has a comparative advantage over other suppliers as a result of its close proximity to these markets, its ability to supply halal product, and the fact that it supplies whole broilers, which many customer countries prefer.

Pasta: With the rapid expansion of its pasta exports, Turkey has become the world’s third-largest exporter of pasta after the EU-28 and China. Most of this pasta is going to Sub-Saharan Africa, where and Turkish pasta has largely replaced Italian pasta in many markets.

Flour: Turkish flour exports have surged, reaching almost $1 billion in 2013 and surpassing two million metric tons, making Turkey the world’s largest exporter of flour . While the majority of Turkish flour goes to Iraq and Syria, exports also go to Asian markets such as the Philippines and Indonesia, and exports have been rising to Sub-Saharan African markets. In fact, flour exports to Sub-Saharan Africa have tripled in the last five years.

Indian Agriculture

The agriculture sector continues to be the backbone of Indian economy contributing approximately 27.4% to the gross domestic product (GDP), and accounts for about 18% share, of total value of country's export. The agricultural production has kept pace with the popular growth rate of 21 % per annum.

Today India is second largest producer of wheat, rice, fruits, vegetables, and fresh water aquaculture; and largest exporter of spices and cashew. The late sixties and seventies were the years of Green Revolution. During Yellow Revolution oilseeds production reached up to 24.4 million tonnes.

Per capita availability of food grains went up to 528.77 g per day in 1996-97 when compared to 395 g in early fifties. Fertilizers consumption has also increased and India has become fourth in the world after USA, USSR and China. Pulse crops are grown on the largest Indian area in the world and India is the first to evolve a cotton hybrid.

Cropping pattern is changing and commercial crops and non-traditional (moong, soya bean, summer groundnut, sunflower etc.) are gradually growing more importance in line with domestic demands and export requirements. Short duration varieties have been introduced to use the residual moisture available from post-kharif and post-rabi cultivation.

The index of agricultural production base T E 1981-82 = 100, recorded following trend

A fall of 2%: 1991-92

An increase of 4. 1 %: 1992-93

An increase of 3.8%: 1993-94

An increase of 4.9%: 1994-95

A fall of 0.4%: 1995-96

Food grain production was quite low after Independence because high-yielding area of Punjab went to Pakistan after division of India. In 1950-51 the food grain production was 51 million tonnes but it was 193.01 million tonnes during 1999-2000 resulting in a buffer stock of 35 million tonnes.

Land:

Land utilization statistics revealed that net sown area increased from 1,187.5 lakh in 1950-51 to 1,424.2 ha in 1998-99. The relative share of food grains and non-food grains in gross increased from 404.8 lakh ha to 682.8 lakh ha in the same duration.

Crops:

The 3 main crop seasons are – kharif, rabi and jayad. Major crops are rice, jowar, bajra, maize, cotton, sesame, soya bean and groundnut. Major rabi crops are wheat, jowar, barley, gram, linseed, rapeseed and mustard. Rice, maize and groundnlit are grown in the summer also.

Seeds:

Three types of seeds, namely, breeder, foundation and certified, are recognized by the system. Indian seed programme include central and state ICAR, SAU system, Public sector, co-operate sector and private sector institutions.

National Seeds Corporation (NSC), State Farms Corporation of India (SFCI), 13 state seed corporation (SSC) and about 100 major private sector seed companies are the main components of Indian Seed, State Seed Certification Agencies (SSCAs) and 19 State Seed Testing Laboratories (SSTLs) looks after quality control and certification. The Seeds Act, 1966, provides

(1) Legislative framework for regulation of quality of seeds sold in the country.

(2) System of certification of seeds sold in India.

(3) Notification of varieties, a pre-requisite certification Administration of the Act and quality control of seeds to look after by control solved committee and its various sub-committees and Central Seed Certification Board.

Seed has been declared an essential commodity under the Essential Commodities Act, 1955. The Seed (Control) Order 1983, was promulgated to control and regulate the seed production and distribution. The new seed policy on seed development has been in operation since 1988.

The main aim of seed policy is to makes available the best quality seed planting material "to farmer" anywhere in the world. Plants, fruits and seeds (Regulation of import into India) Order, 1989, regulates the plant quarantine clearance. Export of seeds is liberally allowed, only certain categories of seeds and planting material are in list of restricted climate for which a license is required.

National Seeds Project III (NSP III) aimed at overall important in seed quality programme. Since 1969, the Central Seed Committee has verified 2,385 varieties of agricultural and horticultural crops.

Fertilizer:

The consumption of chemical fertilizer during 1999-2000 is estimated to be more than 14.93 million tonnes. Sharp increase in prices and introduction of bio fertilizers result in its lower consumption.

The Government of India is implementing two Sponsored schemes: (i) balanced and use of fertilizers to popularize the use of organic sources of nutrients (compost, green manure, bio fertilizers; etc., and (ii) National Project and Technology Mission on Development and Use of Bio fertilizers – to give adequate thrust to bio fertilizer production and promotion under Essential Commodities Act, 1955.

The government has issued Fertilizer Control Order, 1985. The government has been implementing a Central Sector Scheme on strengthening of Central Fertilizer Quality Control and Training Institute since Fourth Plan.

Soil and Water Conservation:

Soil and water conservation measures were launched in First Five-Year Plan. Till the end of 1995- 96, 15.22% of the treatable area had been treated in the area catchment of River Valley Project. Under Flood Prone River Scheme 10.25% area of the total treatable area had been treated till the end of 1995- 96.

Under the Seventh Five-Year Plan, a centrally-sponsored scheme of reclamation of alkali user soils was initiated in Haryana, Punjab, and Uttar Pradesh. It was extended to Gujarat, Madhya Pradesh and Rajasthan.

During 8th Plan Watershed Development Project in Shifting Cultivation Areas (V/DPSCA) has been initiated in north-eastern states. It was in accordance with the guideline of the on-going centrally scheme of National Watershed Development Project Rainfed Area (NWDPRA).

Agricultural Implements and Machinery:

Farmers have been provided assistance for owning agricultural machinery including tractors. Besides this farm machines are exhausted for their characteristics and betterment. Five states agricultural universities are being aided for farm machinery testing, training and human resources development. In spite of the efforts the improvement in farm machinery use has been mainly northern states and in few areas where irrigation facilities have been developed.

Sale of tractors (220.937) and power-tillers (11,000) touched the all time high work in 1996-97, and because of this at farm available power in 1.10 hp/ha in 1996 compared to 0.35 hp/ha in early 70’s. During the Ninth Plan, the main emphasis was on improving and popularizing animal/power driven implements and small farms.

Water saving devices like sprinkles and drip irrigation were given main importance. During Eighth plan, centrally-sponsored scheme, promotion of agricultural mechanization, small farmers was launched and under it 30% subsidy limited to Rs. 30,000 was given to farmers, then groups, etc.

During Ninth plan two schemes, viz. (a) promoting/popularization of agricultural equipments in north- eastern states, (b) conducting studies and formulating long-term mechanization strategies for each agro-climatic zone, were started. State Agro-Industries Corporation (SAICSs) act as catalyst for providing to the farmers access to various industrial inputs for agriculture. Power threshers has been brought under Dangerous Machines (Regulation) Act because of increasing awareness on safety measure among users.

Plant Protection:

Integrated Pest Management (IPM), in eco-friendly approach, was adopted as a major thrust area of crop protection during 8th plan. IPM aims at minimal use of hazardous chemical pesticides by using alternate pest control methods and technique. The surveillance for pests and diseases on economically important crop was carried out and about 1,603 million bio-agents were released.

Bacillus neem-based bio-pesticides are being granted regular registration status under the Insecticides Act, 1968. BHC, Aldirin, cheorclane, Heptachlor were banned with effect from April 1997 and 20 September, 1996, respectively.

The plant guarantee activities aim at presenting introduction of exotic pests and diseases into the country by adopting domestic plant qurantine regulation. It also works for controlling / containing of those exotic diseases/pests already introduced in the country.

Destructive Insecticides and Pests Act (DIP Act) and Plants, Fruits and Seeds (Regulation of Import into India) Order, 1989 (PFS order) are implanted under this scheme. Phytosanitary certificate (PC) as per provisions of International Protection Convention (IPC), 1951 of FAO, is also supplied under these activities.

The post-entry quarantine stations located at 10 international airports, seaports, and 7 land frontiers. National Plant Protection Training Institute, Hyderabad, provides training in various airports of Plant Protection.

Dry land/Rainfed Farming:

Total net sown area in the country is about 142 million ha and out of it 92.6 million ha is rainfed. Production has wide fluctuation due to variation in rainfall as whole farming depends upon rainfall which is often erratic and unpredictable. Jowar, bajra other millets pulses, oilseeds and cotton are grown.

Increase and stability in their productivity is of crucial importance. In the 8th plan holistic approach was adopted under the National Watershed Development Project for Rainfed Area (N WDPRA). It aimed at development of integrated farming system on watershed basin in shifted areas.

The NWDPRA was launched in 1990-91, with the objective of restoration of ecological balances in rainfed areas and sustainable bio-mass production. It also works for generating employment opportunities for rural manner in rainfed areas by developing self-help groups.

Under this project the target is of treating 28 million ha area. The Integrated Watershed Development Project (Hills) and Integrated Watershed Development Project (Plains) are underway and their main aim is slow down and reverse degradation of natural environment and improve potential of the areas.

Agricultural Development Projects (ADPs) with the assistance of World Bank are being implemented to (i) enhance long-time sustainability in agriculture, and (ii) create infrastructure in rural area.

DANIDAG (Government of Denmark), EEC (European Economic Community) and SDC (Swiss Development Corporation) are playing vital role in aided agricultural development programmes.

Technology Mission:

The Technology Mission on oilseeds provided the necessary breakthrough in oilseeds production. Oilseeds sector has now become to major foreign exchange earner. The oilseed production was doubled in decade (12.6 mt in 1987-88 to 24.4 mt 1996-97).

Time is popularly famous as Yellow Revolution. Pulses and maize were also brought under the ambit of Technology Mission. Centrally-sponsored Oilseeds Production Programme (OPP), National Pulses Development Project (NPDP), and Accelerated Maize Development Programme (AMDP) are being continued in 9th Plan also.

Horticulture:

The production of fruits and vegetables was 38.3 and 67.24 million tonnes respectively. India attained second position in coconut production. Above 10% of coconut production is from Kerala, Tamil Nadu, Andhra Pradesh, and Karnataka. India is the worlds, leading producer and exporter of cashew accounting for nearly world’s 50% demand.

Animal Husbandry:

The gross value of output from livestock sector, at current price, was about Rs. 827 billion in 1995- 96 about 26% of value of total output agricultural sector excluding animal draught buffaloes, 50.8 million sheep, 115.3 million goats, 12.8 million pigs, 3 million pack animals and 307 million poultry.

The Operation Flood Programme, the world’s, largest integrated dairy development programmes, completed its III phase in 1996. By September 1990, about 73,300 dairy cooperatives were organized including about 9.4 million farmers.

The average milk procurement in July 1997 was 107.3 lakh litre milk/day and average milk marketed per day was 112 lakh litre milk per day. More than 62% milk procurement was from marginal, small and landless farmers.

The milk production was almost stagnant between 1947 and 1978 with an annual growth rate of merely 1%, but after that Operation Flood Programme a growth rate 4.5% per annum was observed.

In 1996-97, the milk production was 69 million ml tonnes. In 1969-70 the milk availability per capita was only 107 ml/day which increased to 202 ml/day in 1996-97, which is still under the recommended nutritional requirement of 220 ml/day as per Indian Council of Medical Research.

The Government of India launched Technology Mission on Dairy Development (TMDD) in August 1988 to accelerate the pace of Dairy Development in country and reached to first position in the world. Father of White Revolution is Prof. (Dr.) V. Kurien.

Fisheries:

Blue Revolution by enhancing fish production from 0.75 million mt in 1951 to 5.4 million mt in 1997 put India as second largest fish producing country in the world in fresh water aquaculture. Fish production increased at an average rate of 4.4% 1 year during the five years of 8th Five-Year Plan.

Fish Farmers’ Development Agencies (FFDAs), an important programme, was launched by the government to improve overall production of inland fisheries in India. These agencies brought about 3.87 lakh ha water area under intensive fish culture.

There are 6 major fishing harbours viz. Cochin, Chennai, Vishakhapatnam, Roychowk and Paradip, and 41 minor fishing harbours and fish landing centres. Brackish-water Fish Fanners. Development agencies are trying to improve the country's' vast brackish-water area for shrimp culture.

Guidelines have also been issued for mitigating the adverse impact if any, of farming on the coastal eco-system. The government of India started two important schemes for the welfare of traditional fishermen. These are – (i) Group Accident Insurance Scheme, and (ii) Development of Model Fisherman Villages.

Agricultural Census:

As a part of the World United Nations Agricultural Census Programme in pursuance of the recommendation of the FAO, the Department of Agriculture and Cooperation has organized census on quinquennial basis since 1970-71 (1970-71, 1980-81, 1985-86, 1991-92, 2000-01). Sixth agricultural census with reference 1995-96 is in operation.

According to report of 1990-91, operational holdings in the country has increased from 972 million in 1985-86 to 1,066 million in 1990-91 and operated area has risen by 0.6%. The press of population on land with average size sure of holding decreased from 1. 69 ha in 1985-86 to 1.55 ha in 1990-91.

Holdings operated by scheduled castes has increased by 11. 5% and by scheduled tribes by 4.2% from 1985-86 to 1990-91. In 1901 the population in rural area was 89.2% while in 1991 it reduced 74.3%. In 1991 the total number of villages was 580,781 out which 1, 12,803 are in Uttar Pradesh only.

NABARD:

National Bank for Agriculture and Rural Development (NABARD) was launched on 12 July, 1982. It was established for promotion of agriculture, rural-side industries, village industries, handicrafts and other activities in rural areas to promote rural development.

Social Security Group Scheme:

Landless Agriculture Labourers Group Insurance (LALGI) Scheme is in operation since 1987. It takes care of heads of families in the age group of 18-60 years and who are not land holders. Under IRDP a Group Life Insurance Scheme is being separated for which entire premium is paid by the central government.

Farm and Home Programmes:

The average duration of farm and home broadcast 60-100 min. Farm schools as method of communicating distant education on fanning have been adopted by All India Radio stations located in different regions. Akashvani Annual Award is given away to best Farm and Home Programmes of the year.

Agricultural Extension:

The Directorate of Extension (DoE) undertake agricultural extension programme of the Government of India.

The National Institute of Agricultural Extension Management (MANAGE) at Hyderabad, looks after the human resource development activities of Directorate of Extension (DoE). DANIDA is helping agricultural training.

Agricultural Research and Education:

The Indian Council of Agricultural Research is directly involved in undertaking fundamental as well as applied research in traditional and frontier areas to offer solution to problems relating to agriculture.

The research is carried out through a chain of 45 institutes and 4 national bureaux, 30 national research centres, 10 project directorates, 80 All India Coordinated Research Projects, 4 National Institutes and Deemed-to-be university status, 31 State Agricultural Universities and 200 zonal research stations.

The whole country has been divided into 120 district agro-climatic zones. Large network of front-line ICAR-SAU extension system consists of 261 Krishi Vigyan Kendras, 8 Trainers., Training centres (TTC) and 42 Institutions Village-Linkage Programme (IVLP). The 1VLP was started for technology assessment and refinement.

The ICAR has established Agricultural Information System (ARIS). A WAN connecting SAUs, ICAR institutes/headquarters has been established. Connectivity is provided through dial-up, leased line, RF links and VSAT (100). It allows E-mail, Internet browsing- file transfer etc.

National Agricultural Technology Project (NATP):

The NATP was jointly prepared by the ICAR and Department of Agricultural Cooperation (DOAC), and for this the World Bank assured assistance of Rs 200 million. Its main aim is technology generation and its transfer. Its three major components are – Agro-ecosystem Research, innovations in technology dissemination, organization and management system.

Future Plan:

The perspective plans Vision 2020 formulated up to 2020 AD for sustainable growth of Indian agriculture. The required per cent growth in production of various commodities over the 1994-96 average to meet the demand of by 2020 and is very high.

Items	Growth Rate % over the 1994-96
Foodgrains	55
Fruits	142
Milk	28
Meat	57

Agriculture Development in India

The world is witnessing fluctuations in terms of agricultural and farming land, this increases the demand of formatting agricultural cooperatives that ensure high supply of agricultural goods. India has been one of the most productive countries when it comes to agricultural products India. Rural India has shown a significance and steady increase in farming development to produce comparatively higher amount to meet the demand of rising nation. According to recent trends, onions are front-page news these days across newspapers in Delhi. Onion prices, along with those of several other vegetables, have been steadily rising. This clearly shows that there is an acute lack of government agricultural services and less access to advance technology. Hence, the current scenario indicates the vast inefficiencies across the agricultural supply chain in India.

India has much potential to attain increased agricultural production , despite a glut of seemingly pro-agriculture subsidies, policies and sops given to the agricultural community by successive governments, the outlook on India's farm economy remains anything but healthy. Prices rise when supply does not keep up with demand. Thousands of tons of grains are wasted because of lack of storage and transport facilities, even as farming remains a gritty battle of a profession. Noticeably, the multitude of state or central policies and short-term thinking has only made Indian agriculture unsustainable, although there was some good news in 2012 published in a local newspaper: India overtook Thailand as the world's largest rice exporter, and emerged as the world's top exporter of buffalo meat (known as carabeef in the global market).

According to IFFCO associates, "The problem in most of the areas in rural India is that resources are there but their proper channelization is lacking." IFFCO is actively researching in the field of agricultural development, the corporation has over 50 million members in 40,000 member cooperatives, Indian Farmers Fertiliser Cooperative (IFFCO) is one of the biggest agricultural cooperatives in the world, generating over $5 billion of turnover. Recently another article published in a magzine where Agricultural scientist Professor M S Swaminathan said, "unless a productivity-cum-quality revolution take place the apprehension voiced by experts about the India becoming a net importer of food grains in another 20-30 years cannot be ignored."

Majorly agriculture in rural India is disturbed from policy inconsistency and backwardness of technology. On the other hand, the central government of India seems totally allergic to consistent agriculture policies. It seems out of the question to progress agriculture cooperatives in India, if the government changes every policy without giving the earlier policy a chance to show its possible impact, and benefit. There are an incredible number of dramatic policy shifts - look at the way we ban exports on sugar, the way we ban exports on cotton, or how we create a futures exchange, then ban half the items listed on the future list when global prices go up.

IFFCO has raised a campaign named as "Save the Soil Campaign / BHOOMI BACHAO ABHIYAN", to contribute to rural agriculture land in India. The objective is to rejuvenation the fertile properties of soil by executing Fertiliser Subsidy Policy and it helps farmers in attaining agriculture information to increase production gradually. Results of this project are encouraging as crop productivity of the area has gone up by about 20-24% and farmers are getting benefits through various interventions.

Agriculture in China

Agriculture is a vital industry in China, employing over 300 million farmers. China ranks first in worldwide farm output, primarily producing rice, wheat, potatoes, tomato, sorghum, peanuts, tea, millet, barley, cotton, oilseed and soybeans. Although accounting for only 10 percent of arable land worldwide, it produces food for 20 percent of the world's population.

The development of farming over the course of China's history has played a key role in supporting the growth of what is now the largest population in the world. Analysis of stone tools by Professor Liu Li and others has shown that the origins of Chinese agriculture is rooted in the pre-agricultural Paleolithic. During this time, hunter-gatherers harvested wild plants with the same tools that would later be used for millet and rice.

Remains of domesticated millet have been found in northern China at Xinglonggou, Yuezhang, Dadiwan, Cishan, and several Peiligang sites. These sites cover a period over 6250-5050 BCE. The amount of domesticated millet eaten at these sites was proportionally quite low compared to other plants. At Xinglonggou, millet made up only 15% of all plant remains around 6200-5400 BCE; a ratio that changed to 99% by 2050-1550 BCE. Experiments have shown that millet requires very little human intervention to grow, which means that obvious changes in the archaeological record that could demonstrate millet was being cultivated do not exist.

Excavations at Kuahuqiao, the earliest known Neolithic site in eastern China, have documented rice cultivation 7,700 years ago. Approximately half of the plant remains belonged to domesticated japonica species, whilst the other half were wild types of rice. It is possible that the people at Kuahuqiao also cultivated the wild type. Finds at sites of the HemuduCulture (c.5500-3300 BCE) in Yuyao and Banpo near Xi'an include millet and spade-like tools made of stone and bone. Evidence of settled rice agriculture has been found at the Hemudu site of Tianluoshan (5000-4500 BCE), with rice becoming the backbone of the agricultural economy by the Majiabang culture in southern China.

There is also a long tradition involving agriculture in Chinese mythology. In his book Permanent Agriculture: Farmers of Forty Centuries (1911), Professor Franklin Hiram Kingdescribed and extolled the values of the traditional farming practices of China.

Due to China's status as a developing country and its severe shortage of arable land, farming in China has always been very labor-intensive. However, throughout its history, various methods have been developed or imported that enabled greater farming production and efficiency. They also utilized the seed drill to help improve on row farming.

During the Spring and Autumn period (722–481 BC), two revolutionary improvements in farming technology took place. One was the use of cast iron tools and beasts of burden to pull plows, and the other was the large-scale harnessing of rivers and development of water conservation projects. The engineer Sunshu Ao of the 6th century BC and Ximen Bao of the 5th century BC are two of the oldest hydraulic engineers from China, and their works were focused upon improving irrigation systems. These developments were widely spread during the ensuing Warring States period (403–221 BC), culminating in the enormous Du Jiang Yan Irrigation System engineered by Li Bing by 256 BC for the State of Qin in ancient Sichuan.

For agricultural purposes the Chinese had invented the hydraulic-powered trip hammer by the 1st century BC, during the ancient Han Dynasty (202 BC-220 AD). Although it found other purposes, its main function was to pound, decorticate, and polish grain that otherwise would have been done manually. The Chinese also innovated the square-pallet chain pump by the 1st century AD, powered by a waterwheel or an oxen pulling on a system of mechanical wheels. Although the chain pump found use in public works of providing water for urban and palatial pipe systems, it was used largely to lift water from a lower to higher elevation in filling irrigation canals and channels for farmland.

During the Eastern Jin (317–420) and the Northern and Southern Dynasties (420–589), the Silk Road and other international trade routes further spread farming technology throughout China. Political stability and a growing labor force led to economic growth, and people opened up large areas of wasteland and built irrigation works for expanded agricultural use. As land-use became more intensive and efficient, rice was grown twice a year and cattle began to be used for plowing and fertilization.

By the Tang Dynasty (618–907), China had become a unified feudal agricultural society. Improvements in farming machinery during this era included the moldboard plow and watermill. Later during the Yuan Dynasty (1271–1368), cotton planting and weaving technology were extensively adopted and improved.

While around 750, 75% of China's population lived north of the river Yangtze, by 1250, 75% of the population lived south of the river. Such large-scale internal migration was possible due to the introduction of quick-ripening strains of rice from Vietnam suitable for multi-cropping.

The Qing, Ming and Yuan dynasties had seen the rise of collective help organizations between farmers.

In 1909 US Professor of Agriculture Franklin Hiram King made an extensive tour of China (as well as Japan and briefly Korea) and he described contemporary agricultural practices. He favourably described the farming of China as 'permanent agriculture' and his book 'Farmers of Forty Centuries', published posthumously in 1911, has become an agricultural classic and has been a favoured reference source for organic farming advocates.

Following the Communist Party of China's victory in the Chinese Civil War, control of the farmlands was taken away from landlords and redistributed to the 300 million peasant farmers. In 1952, gradually consolidating its power following the civil war, the government began organizing the peasants into teams. Three years later, these teams were combined into producer cooperatives, enacting the Socialist goal of collective land ownership. In the following year, 1956, the government formally took control of the land, further structuring the farmland into large government-operated collective farms.

In the 1958 "Great Leap Forward" campaign initiated by Mao Zedong, land use was placed under closer government control in an effort to improve agricultural output. In particular, the Great sparrow campaign had a direct negative impact on agriculture. Collectives were organized into communes, private food production was banned, and collective eating was required. Greater emphasis was also put on industrializationinstead of agriculture. The farming inefficiencies created by this campaign led to The Great Chinese Famine, resulting in the deaths of somewhere between the government estimate of 14 million to scholarly estimates of 20 to 43 million. Although private plots of land were re-instated in 1962 due to this failure, communes remained the dominant rural unit of economic organization during the Cultural Revolution, with Mao championing the "Learn from Tachai" campaign. Tachai's semiliterate party secretary Chen Yonggui was among those outmaneuvered by Deng Xiaoping after the death of Mao: from 1982–1985, the Dazhai-style communes were gradually replaced by townships.

Beginning in 1978, as part of the Four Modernizations campaign, the Family Production Responsibility System was created, dismantling communes and giving agricultural production responsibility back to individual households. Households are now given crop quotas that they were required to provide to their collective unit in return for tools, draft animals, seeds, and other essentials. Households, which now lease land from their collectives, are free to use their farmland however they see fit as long as they meet these quotas. This freedom has given more power to individual families to meet their individual needs. In addition to these structural changes, the Chinese government also engages in irrigation projects (such as the Three Gorges Dam), runs large state farms, and encourages mechanization and fertilizer use.

By 1984, when about 99% of farm production teams had adopted the Family Production Responsibility System, the government began further economic reforms, aimed primarily at liberalizing agricultural pricing and marketing. In 1984, the government replaced mandatory procurement with voluntary contracts between farmers and the government. Later, in 1993, the government abolished the 40-year-old grain rationing system, leading to more than 90 percent of all annual agricultural produce to be sold at market-determined prices.

Since 1994, the government has instituted a number of policy changes aimed at limiting grain importation and increasing economic stability. Among these policy changes was the artificial increase of grain prices above market levels. This has led to increased grain production, while placing the heavy burden of maintaining these prices on the government. In 1995, the "Governor’s Grain Bag Responsibility System" was instituted, holding provincial governors responsible for balancing grain supply and demand and stabilizing grain prices in their provinces. Later, in 1997, the "Four Separations and One Perfection" program was implemented to relieve some of the monetary burdens placed on the government by its grain policy.

As China continues to industrialize, vast swaths of agricultural land is being converted into industrial land. Farmers displaced by such urban expansion often become migrant labor for factories, but other farmers feel disenfranchised and cheated by the encroachment of industry and the growing disparity between urban and rural wealth and income.

The most recent innovation in Chinese agriculture is a push into organic agriculture. This rapid embrace of organic farming simultaneously serves multiple purposes, including food safety, health benefits, export opportunities, and, by providing price premiums for the produce of rural communities, the adoption of organics can help stem the migration of rural workers to the cities. In the mid-1990s China became a net importer of grain, since its unsustainable practises of groundwater mining has effectively removed considerable land from productive agricultural use.

Although China's agricultural output is the largest in the world, only about 15% of its total land area can be cultivated. China's arable land, which represents 10% of the total arable land in the world, supports over 20% of the world's population. Of this approximately 1.4 million square kilometers of arable land, only about 1.2% (116,580 square kilometers) permanently supports crops and 525,800 square kilometers are irrigated. The land is divided into approximately 200 million households, with an average land allocation of just 0.65 hectares (1.6 acres).

China's limited space for farming has been a problem throughout its history, leading to chronic food shortage and famine. While the production efficiency of farmland has grown over time, efforts to expand to the west and the north have met with limited success, as such land is generally colder and drier than traditional farmlands to the east. Since the 1950s, farm space has also been pressured by the increasing land needs of industry and cities.

Such increases in the sizes of cities, such as the administrative district of Beijing's increase from 4,822 km² in 1956 to 16,808 km² in 1958, has led to the increased adoption of peri-urban agriculture. Such "suburban agriculture" led to more than 70% of non-staple food in Beijing, mainly consisting of vegetables and milk, to be produced by the city itself in the 1960s and 1970s. Recently, with relative food security in China, periurban agriculture has led to improvements in the quality of the food available, as opposed to quantity. One of the more recent experiments in urban agriculture is the Modern Agricultural Science Demonstration Park in Xiaotangshan.

About 75% of China's cultivated area is used for food crops. Rice is China's most important crop, raised on about 25% of the cultivated area. The majority of rice is grown south of the Huai River, in the Zhu Jiang delta, and in the Yunnan, Guizhou, and Sichuan provinces.

Wheat is the second most-prevalent grain crop, grown in most parts of the country but especially on the North China Plain, the Wei and Fen River valleys on the Loess plateau, and in Jiangsu, Hubei, and Sichuan provinces. Corn and milletare grown in north and northeast China, and oat is important in Inner Mongolia and Tibet.

Other crops include sweet potatoes in the south, white potatoes in the north, and various other fruits and vegetables. Tropical fruits are grown on Hainan Island, apples and pears are grown in northern Liaoning and Shandong.

Oil seeds are important in Chinese agriculture, supplying edible and industrial oils and forming a large share of agricultural exports. In North and Northeast China, Chinese soybeans are grown to be used in tofu and cooking oil. China is also a leading producer of peanuts, which are grown in Shandong and Hebei provinces.

Other oilseed crops are sesame seeds, sunflower seeds, rapeseed, and the seeds of the tung tree.

Citrus is a major cash crop in southern China, with production scattered along and south of the Yangtze River valley. Mandarins are the most popular citrus in China, with roughly double the output of oranges.

Other important food crops for China include green and jasmine teas (popular among the Chinese population), black tea (as an export), sugarcane, and sugar beets. Tea plantations are located on the hillsides of the middle Yangtze Valley and in the southeast provinces of Fujian and Zhejiang. Sugarcane is grown in Guangdong and Sichuan, while sugar beets are raised in Heilongjiang province and on irrigated land in Inner Mongolia. Lotus is widely cultivated throughout southern China. Arabica coffee is grown in the southwestern province of Yunnan.

China is the leading producer of cotton, which is grown throughout, but especially in the areas of the North China Plain, the Yangtze river delta, the middle Yangtze valley, and the Xinjiang Uygur Autonomous Region. Other fiber crops include ramie, flax, jute, and hemp. Sericulture, the practice of silkworm raising, is also practiced in central and southern China.

China has a large livestock population, with pigs and fowls being the most common. China's pig population and pork production mainly lie along the Yangtze River. In 2011, Sichuan province had 51 million pigs (11% of China's total supply) . In rural western China, sheep, goats, and camels are raised by nomadic herders. In Tibet, yaks are raised as a source of food, fuel, and shelter. Cattle, water buffalo, horses, mules, and donkeys are also raised in China, and dairy has recently been encouraged by the government, even though approximately 92.3% of the adult population is affected by some level of lactose intolerance.

As demand for gourmet foods grows, production of more exotic meats increases as well. Based on survey data from 684 Chinese turtle farms (less than half of the all 1,499 officially registered turtle farms in the year of the survey, 2002), they sold over 92,000 tons of turtles (around 128 million animals) per year; this is thought to correspond to the industrial total of over 300 million turtles per year.

Increased incomes and increased demand for meat, especially pork, has resulted in demand for improved breeds of livestock, breeding stock imported particularly from the United States. Some of these breeds are adapted to factory farming.

China accounts for about one-third of the total fish production of the world. Aquaculture, the breeding of fish in ponds and lakes, accounts for more than half of its output. The principal aquaculture-producing regions are close to urban markets in the middle and lower Yangtze valley and the Zhu Jiang delta.

Despite rapid growth in output, the Chinese agricultural sector still faces several challenges. Farmers in several provinces, such as Shandong, Zhejiang, Anhui, Liaoning, and Xinjiang often have a hard time selling their agricultural products to customers due to a lack of information about current conditions.

Between the producing farmer in the countryside and the end-consumer in the cities there is a chain of intermediaries. Because a lack of information flows through them, farmers find it difficult to foresee the demand for different types of fruits and vegetables. In order to maximize their profits they, therefore, opt to produce those fruits and vegetables that created the highest revenues for farmers in the region in the previous year. If, however, most farmers do so, this causes the supply of fresh products to fluctuate substantially year on year. Relatively scarce products in one year are produced in excess the following year because like of expected higher profit margins. The resulting excess supply, however, forces farmers to reduce their prices and sell at a loss. The scarce, revenue creating products of one year become the over-abundant, loss-making products in the following, and vice versa.

Efficiency is further impaired in the transportation of agricultural products from the farms to the actual markets. According to figures from the Commerce Department, up to 25% of fruits and vegetables rot before being sold, compared to around 5% in a typical developed country. As intermediaries cannot sell these rotten fruits they pay farmers less than they would if able to sell all or most of the fruits and vegetables. This reduces farmer’s revenues although the problem is caused by post-production inefficiencies, which they are not themselves aware of during price negotiations with intermediaries.

These information and transportation problems highlight inefficiencies in the market mechanisms between farmers and end consumers, impeding farmers from taking advantage of the fast development of the rest of the Chinese economy. The resulting small profit margin does not allow them to invest in the necessary agricultural inputs (machinery, seeds, fertilizers, etc.) to raise productivity and improve their standards of living, from which the whole of the Chinese economy would benefit. This in turn increases the exodus of people from the countryside to the cities, which already face urbanization issues.

China is the world's largest importer of soybeans and other food crops, and is expected to become the top importer of farm products within the next decade.] In 2017, farmers in the providence of Donggaozhuang began selling yarn in an online marketplace owned by Alibaba Group. Many farmers later sold their farmland to focus on online sales as the access to global consumers yielded much more income then traditional farming.

While most years China's agricultural production is sufficient to feed the country, in down years, China has to import grain. Due to the shortage of available farm land and an abundance of labor, it might make more sense to import land-extensive crops (such as wheat and rice) and to save China's scarce cropland for high-value export products, such as fruits, nuts, or vegetables. In order to maintain grain independence and ensure food security, however, the Chinese government has enforced policies that encourage grain production at the expense of more-profitable crops. Despite heavy restrictions on crop production, China's agricultural exports have greatly increased in recent years.

One important motivator of increased international trade was China's inclusion in the World Trade Organization (WTO) on December 11, 2001, leading to reduced or eliminated tariffs on much of China's agricultural exports. Due to the resulting opening of international markets to Chinese agriculture, by 2004 the value of China's agricultural exports exceeded $17.3 billion (US). Since China's inclusion in the WTO, its agricultural trade has not been liberalized to the same extent as its manufactured goods trade. Markets within China are still relatively closed-off to foreign companies. Due to its large and growing population, it is speculated that if its agricultural markets were opened, China would become a consistent net importer of food, possibly destabilizing the world food market. The barriers enforced by the Chinese government on grains are not transparent because China’s state trading in grains is conducted through its Cereal, Oil, and Foodstuffs Importing and Exporting Corporation (COFCO).

As a developing nation, China has relatively low sanitary and phytosanitary (SPS) standards for its agricultural goods. Corruption in the government, such as the bribery of the former head of the State Food and Drug Administration Zheng Xiaoyu, has also complicated China's regulation difficulties. Excessive pesticide residues, low food hygiene, unsafe additives, contamination with heavy metals and other contaminants, and misuse of veterinary drugs have all led to trade restrictions with developed nations such as Japan, the United States, and the European Union. These problems have also led to public outcry, such as in the melamine-tainted dog food scare and the carcinogenic-tainted seafood import restriction, leading to measures such as the "China-free" label.

About one tenth of China's farmland is contaminated with heavy metals, according to the Ministry of Environmental Protection of the People's Republic of China.

China has developed a Green Food program where produce is certified for low pesticide input. This has been articulated into Green food Grade A and Grade AA. This Green Food AA standard has been aligned with IFOAM international standards for organic farming and has formed the basis of the rapid expansion of organic agriculture in China.

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